

**UTILITY PATENT APPLICATION TRANSMITTAL**  
**(Large Entity)**

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Docket No.  
JEL 31064

Total Pages in this Submission

**TO THE ASSISTANT COMMISSIONER FOR PATENTS**

Box Patent Application

Washington, D.C. 20231

Transmitted herewith for filing under 35 U.S.C. 111(a) and 37 C.F.R. 1.53(b) is a new utility patent application for an invention entitled:

**OFDM COMMUNICATION APPARATUS**

and invented by:

Hiroaki SUDO  
Kimihiro ISHIKAWA

jc571 U.S. PTO  
09/555167  
04/14/00

If a CONTINUATION APPLICATION, check appropriate box and supply the requisite information:

Continuation    Divisional    Continuation-in-part (CIP) of prior application No.: \_\_\_\_\_

Which is a:

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Enclosed are:

**Application Elements**

1.  Filing fee as calculated and transmitted as described below
2.  Specification having 57 pages and including the following:
  - a.  Descriptive Title of the Invention
  - b.  Cross References to Related Applications (*if applicable*)
  - c.  Statement Regarding Federally-sponsored Research/Development (*if applicable*)
  - d.  Reference to Microfiche Appendix (*if applicable*)
  - e.  Background of the Invention
  - f.  Brief Summary of the Invention
  - g.  Brief Description of the Drawings (*if drawings filed*)
  - h.  Detailed Description
  - i.  Claim(s) as Classified Below
  - j.  Abstract of the Disclosure

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Total Pages in this Submission

**Application Elements (Continued)**

3.  Drawing(s) (when necessary as prescribed by 35 USC 113)
  - a.  Formal Number of Sheets 24
  - b.  Informal Number of Sheets \_\_\_\_\_
4.  Oath or Declaration
  - a.  Newly executed (*original or copy*)  Unexecuted
  - b.  Copy from a prior application (37 CFR 1.63(d)) (*for continuation/divisional application only*)
  - c.  With Power of Attorney  Without Power of Attorney
  - d.  **DELETION OF INVENTOR(S)**  
Signed statement attached deleting inventor(s) named in the prior application, see 37 C.F.R. 1.63(d)(2) and 1.33(b).
5.  Incorporation By Reference (*usable if Box 4b is checked*)  
The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.
6.  Computer Program in Microfiche (*Appendix*)
7.  Nucleotide and/or Amino Acid Sequence Submission (*if applicable, all must be included*)
  - a.  Paper Copy
  - b.  Computer Readable Copy (*identical to computer copy*)
  - c.  Statement Verifying Identical Paper and Computer Readable Copy

**Accompanying Application Parts**

8.  Assignment Papers (*cover sheet & document(s)*)
9.  37 CFR 3.73(B) Statement (*when there is an assignee*)
10.  English Translation Document (*if applicable*)
11.  Information Disclosure Statement/PTO-1449  Copies of IDS Citations
12.  Preliminary Amendment
13.  Acknowledgment postcard
14.  Certificate of Mailing  
 First Class  Express Mail (*Specify Label No.:*) \_\_\_\_\_

**UTILITY PATENT APPLICATION TRANSMITTAL  
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Total Pages in this Submission

**Accompanying Application Parts (Continued)**

15.  Certified Copy of Priority Document(s) (*if foreign priority is claimed*)

16.  Additional Enclosures (*please identify below*):

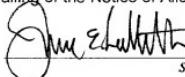
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**Fee Calculation and Transmittal**

**CLAIMS AS FILED**

For	#Filed	#Allowed	#Extra	Rate	Fee
Total Claims	18	- 20 =	0	x \$18.00	\$0.00
Indep. Claims	4	- 3 =	1	x \$78.00	\$78.00
Multiple Dependent Claims (check if applicable)	<input type="checkbox"/>				
<b>BASIC FEE</b>					\$690.00
<b>OTHER FEE (specify purpose)</b>					\$0.00
<b>TOTAL FILING FEE</b>					\$768.00

- A check in the amount of **\$768.00** to cover the filing fee is enclosed.
- The Commissioner is hereby authorized to charge and credit Deposit Account No. **19-4375** as described below. A duplicate copy of this sheet is enclosed.
- Charge the amount of \_\_\_\_\_ as filing fee.
- Credit any overpayment.
- Charge any additional filing fees required under 37 C.F.R. 1.16 and 1.17.
- Charge the issue fee set in 37 C.F.R. 1.18 at the mailing of the Notice of Allowance, pursuant to 37 C.F.R. 1.311(b).



*Signature*

Dated: **April 14, 2000**

**James E. Ledbetter**  
Reg. No. 28,732  
Stevens, Davis, Miller & Mosher, LLP  
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202/408-5100

CC:

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of

Inventor(s): Hiroaki SUDO et al.

Serial No.: New Patent Application

Filed: April 14, 2000

For: OFDM COMMUNICATION APPARATUS

PRELIMINARY AMENDMENT

Assistant Commissioner of Patents  
Washington, DC 20231

Sir:

Please amend the above application as follows:

IN THE CLAIMS

Please amend the claims as follows:

Claim 7, line 2, delete "or claim 3".

Claim 8, line 2, delete "or claim 6".

Please add the following new claims:

17. The OFDM communication apparatus according to claim 3,  
wherein the interval of the correlation value suppression signal  
is shorter than the cycle of the phase reference symbol.

18. The OFDM communication apparatus according to claim 6,  
wherein the interval of the correlation value suppression signal  
is shorter than the cycle of the synchronization symbol.

Preliminary Amendment - H. SUDO et al.

April 14, 2000

Page 2

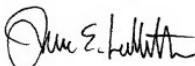
REMARKS

This Preliminary Amendment eliminates the multiple dependent claim status of claims 7 and 8 in order to avoid the multiple dependent claim surcharge.

New claims 17 and 18 are added in order to recapture the subject matter deleted in the amendment to claims 7 and 8.

Early and favorable consideration of this application is respectfully requested.

Respectfully submitted,



James E. Ledbetter  
Registration No. 28,732

Date: April 14, 2000

JEL/lmq

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# **SPECIFICATION**

Title of the Invention :

**OFDM COMMUNICATION APPARATUS**

Inventor :

**Hiroaki SUDO**

**Kimihiko ISHIKAWA**

## OFDM COMMUNICATION APPARATUS

## BACKGROUND OF THE INVENTION

## 5 Field of the Invention

The present invention relates to an OFDM communication apparatus used in a radio communication system.

## 10 Description of the Related Art

A conventional OFDM communication apparatus is explained using FIG.1. FIG.1 is a block diagram showing a configuration of a conventional OFDM communication apparatus.

15 In the OFDM communication apparatus shown in FIG.1, an information signal for every subcarrier is subjected to digital modulation processing by modulation section 1 through, for example, QPSK (Quadrature Phase Shift Keying) and QAM (Quadrature Amplitude Modulation) and  
20 a synchronization symbol is then inserted into this signal by synchronization symbol insertion section 2.

The signal with the synchronization symbol inserted is subjected to an IFFT (Inverse Fast Fourier Transform) calculation by IFFT section 3 and converted  
25 to an OFDM signal.

A guard interval is inserted into this OFDM signal by guard interval insertion section 4. As shown in FIG.2, this signal frame is configured by synchronization

symbol 21, phase reference symbol or pilot symbol 22, guard interval 23 and valid symbol 24.

The signal with the guard interval inserted is D/A-converted to a baseband signal by D/A converter 5.

- 5 This baseband signal is subjected to normal radio transmission processing by a radio transmission section, which is not shown in the figure, and transmitted from an antenna as a transmission signal.

A signal received via an antenna is subjected to  
10 normal radio reception processing by a radio reception section, which is not shown in the figure, and converted to a baseband signal. This baseband signal is subjected to quasi-coherent detection by a quasi-coherent detector and stripped of an unnecessary frequency component by  
15 a low-pass filter (the quasi-coherent detector and low-pass filter are not shown in the figure). This baseband signal is A/D-converted by A/D converter 6. In addition, the reception signal is divided into an in-phase component and quadrature component through  
20 quasi-coherent detection processing but the figure only shows a single signal path.

- This baseband signal is subjected to an FFT (Fast Fourier Transform) calculation by FFT section 12 and signals assigned to different subcarriers are obtained.  
25 At this time, the baseband signal is delayed by delay section 7, sent to multiplier 8 and the multiplication result is accumulated by accumulator 9. The accumulation result is sent to subtractor 10 to be

subjected to a subtraction with a threshold and subjected to threshold judgment by determination section 11. This determination result is sent to FFT section 12.

The signal FFT-calculated by FFT section 12 is sent  
5 to demodulation section 13, subjected to delay detection,  
judged by determination section 14 as to whether the  
signal is different from a signal one bit ahead and output  
as a demodulated signal.

When symbol synchronization is established in the  
10 OFDM communication apparatus with the configuration  
above, the baseband signal prior to FFT calculation and  
the signal prior to FFT calculation delayed by one symbol  
by delay section 7 are sent to multiplier section 8 to  
be subjected to complex multiplication.

15 Then, the output of multiplier 8 is sent to  
accumulator 9 where the complex multiplication results  
are accumulated. Here, since the phase reference symbol  
is identical to the synchronization symbol, the result  
of accumulation of both signals has a peak on the phase  
20 reference symbol of the signal delayed by one symbol as  
shown in part A of FIG.3. Therefore, it is possible to  
establish symbol synchronization by detecting timing at  
which the accumulation result exceeds a threshold.

However, signals with high power may be included  
25 under circumstances under which tens of delay signals  
are received. In this case, since threshold judgment is  
carried out using power of correlation results, it is  
assumed that a signal with high power may exceed the

threshold. In such a case, symbol synchronization may be established using a signal with high power, failing to correctly detect FFT processing start timing and resulting in desynchronization.

5

#### SUMMARY OF THE INVENTION

The present invention has been implemented taking account of the points described above and it is an 10 objective of the present invention to provide an OFDM communication apparatus capable of correctly detecting FFT processing start timing even under circumstances under which tens of delay signals are received and preventing desynchronization.

15 A main point of the present invention is an insertion of a correlation value suppression signal immediately after a symbol used to pull in synchronization. As a result, when establishing symbol synchronization by carrying out correlation value 20 processing using the reception signal, the receiving side can reduce the correlation result of a signal with high power so that a peak appears only on the correlation value result using the above symbol for the reception signal. This makes it possible to correctly detect FFT 25 processing start timing and implement symbol synchronization free of desynchronization.

#### BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects and features of the invention will appear more fully hereinafter from a consideration of the following description taken in connection with the accompanying drawing wherein one example is illustrated by way of example, in which;

FIG.1 is a block diagram showing a configuration of a conventional OFDM communication apparatus;

FIG.2 is a frame chart of a signal used by the conventional OFDM communication apparatus;

10 FIG.3 is a diagram showing timing of a reception signal and correlation result;

FIG.4 is another frame chart used by the OFDM communication apparatus;

15 FIG.5 is a block diagram showing a configuration of an OFDM communication apparatus according to Embodiment 1 of the present invention;

FIG.6 is a frame chart of a signal used by the OFDM communication apparatus according to the embodiment above;

20 FIG.7 is a block diagram showing a configuration of an OFDM communication apparatus according to Embodiment 2 of the present invention;

FIG.8 is a frame chart of a signal used by the OFDM communication apparatus according to the embodiment above;

25 FIG.9 is a block diagram showing a configuration of an OFDM communication apparatus according to Embodiment 3 of the present invention;

FIG.10 is a block diagram showing a configuration  
of an OFDM communication apparatus according to  
Embodiment 4 of the present invention;

FIG.11 is a block diagram showing a configuration  
5 of an OFDM communication apparatus according to  
Embodiment 5 of the present invention;

FIG.12 is a frame chart of a signal used by the OFDM  
communication apparatus according to the embodiment  
above;

10 FIG.13 is a block diagram showing a configuration  
of an OFDM communication apparatus according to  
Embodiment 6 of the present invention;

FIG.14 is a frame chart of a signal used by the OFDM  
communication apparatus according to the embodiment  
15 above;

FIG.15 is a block diagram showing a configuration  
of an OFDM communication apparatus according to  
Embodiment 7 of the present invention;

FIG.16 is a block diagram showing a configuration  
20 of an OFDM communication apparatus according to  
Embodiment 8 of the present invention;

FIG.17 is a block diagram showing a configuration  
of an OFDM communication apparatus according to  
Embodiment 9 of the present invention;

25 FIG.18 is a block diagram showing a configuration  
of an OFDM communication apparatus according to  
Embodiment 10 of the present invention;

FIG.19 is a block diagram showing a configuration

of an OFDM communication apparatus according to Embodiment 11 of the present invention;

FIG.20 is a block diagram showing an internal configuration of a correlator of the OFDM communication apparatus according to Embodiment 11;

FIG.21 is a block diagram showing a configuration of a hard decision section in a correlator of an OFDM communication apparatus according to Embodiment 12;

FIG.22 is a frame diagram showing a signal used in an OFDM communication apparatus according to Embodiment 13;

FIG.23 is a block diagram showing a configuration of the OFDM communication apparatus according to Embodiment 13; and

FIG.24 is a block diagram showing a configuration of an OFDM communication apparatus according to Embodiment 14 of the present invention.

DETAILED DESCRIPTION OF THE  
PREFERRED EMBODIMENTS

With reference now to the attached drawings, the embodiments of the present invention are explained in detail below.

25

(Embodiment 1)

FIG.5 is a block diagram showing a configuration of an OFDM communication apparatus according to

Embodiment 1 of the present invention.

An information signal for every subcarrier is subjected to digital modulation processing by modulation section 101 through, for example, QPSK (Quadrature Phase Shift Keying) and QAM (Quadrature Amplitude Modulation) and then a synchronization symbol is added to this signal by synchronization symbol insertion section 102 and then a 0 symbol, which is a correlation value suppression signal, is added by 0 symbol insertion section 103.

The signal with these symbols added is subjected to an IFFT (Inverse Fast Fourier Transform) calculation by IFFT section 104 and converted to an OFDM signal. A guard interval is inserted into this OFDM signal by guard interval insertion section 105. The signal with the guard interval inserted is D/A-converted to a baseband signal by D/A converter 106. This baseband signal is subjected to normal radio transmission processing by a radio transmission section, which is not shown in the figure, and transmitted from an antenna as a transmission signal.

A signal received via an antenna is subjected to normal radio reception processing by a radio reception section, which is not shown in the figure, and converted to a baseband signal. This baseband signal is subjected to quasi-coherent detection by a quasi-coherent detector and stripped of an unnecessary frequency component by a low-pass filter (the quasi-coherent detector and low-pass filter are not shown in the figure). This

baseband signal is A/D-converted by A/D converter 107. In addition, the reception signal is divided into an in-phase component and quadrature component through quasi-coherent detection processing but the figure only 5 shows a single signal path.

This baseband signal is subjected to an FFT (Fast Fourier Transform) calculation by FFT section 113 and signals assigned to different subcarriers are obtained. At this time, the baseband signal is delayed by delay 10 section 108, sent to multiplier 109 and the multiplication result is accumulated by accumulator 110. The accumulation result is sent to subtractor 111 to be subjected to a subtraction with a threshold and subjected to threshold judgment by determination section 112. 15 This determination result is sent to FFT section 113.

The signal FFT-calculated by FFT section 113 is sent to demodulation section 114, subjected to delay detection, judged by determination section 115 as to whether the signal is different from a signal one bit 20 ahead and output as a demodulated signal.

Then, the operation of the OFDM communication apparatus with the above configuration is explained using FIG.5 and FIG.6. Synchronization symbol 201 is inserted into the signal digital-modulated by modulation 25 section 101 by synchronization symbol insertion section 102. This synchronization symbol insertion section 102 is made up of a switch and when control signal 1 instructing synchronization symbol 201 to be inserted

is input, this switch is switched to insert synchronization symbol 201. After synchronization symbol 201, phase reference symbol 202 is inserted. This phase reference symbol 202 is identical to 5 synchronization symbol 201. This phase reference symbol 202 is inserted by synchronization symbol insertion section 102 in like manner.

0 symbol insertion section 103 inserts 0 symbol 203 into the signal with synchronization symbol 201 inserted. 10 This 0 symbol insertion section 103 is made up of a switch and when control signal 2 instructing 0 symbol 203 to be inserted is input, this switch is switched to insert 0 symbol 203.

The signal with synchronization symbol 201 and 0 15 symbol 203 inserted is sent to IFFT section 104 and subjected to an IFFT calculation. That is, IFFT section 104 obtains a signal waveform on the time axis by IFFT-transforming complex number data including information on the phase and amplitude on the frequency 20 axis onto the time axis for every symbol cycle.

Then, guard interval 204 is inserted into the IFFT-transformed signal waveform by guard interval insertion section 105. More specifically, part of a waveform of the last edge of valid symbol 205 is inserted 25 as guard interval 204. In this way, it is possible to suppress an increase in the bit error rate and improve multi-path resistance by inserting guard interval 204 that allows a delay time.

Then, the signal with this guard interval inserted is D/A-converted by D/A converter 106. Then, the D/A-converted signal is subjected to normal radio transmission processing and then transmitted. That is,  
5 the above signal is frequency-converted and amplified by a radio transmission section, which is not shown in the figure, and transmitted from an antenna.

On the other hand, a signal received from an antenna is subjected to normal radio reception processing. That  
10 is, the reception signal is subjected to amplification, frequency conversion and A/D conversion to become a baseband signal by a radio reception section, which is not shown in the figure. As described above, the reception signal is divided into an in-phase component  
15 and quadrature component by a quasi-coherent detector, which is not shown in the figure, and processed, but these are expressed as one path in the figure.

Here, for the baseband signal, symbol synchronization is established using a guard interval.  
20 The method of establishing this symbol synchronization (synchronization pull-in method) is explained below.

First, the baseband signal prior to FFT calculation and the signal prior to FFT calculation delayed by one symbol by delay section 108 are sent to multiplier 109  
25 to be subjected to complex multiplication.

Then, the output of multiplier 109 is sent to accumulation section 110, which accumulates the complex multiplication results. Here, since the phase

reference symbol is identical to the synchronization symbol, the accumulation result of both symbols has a peak on a phase reference symbol of the signal delayed by a unit symbol (here 1 symbol) as shown in part A of FIG.3. Therefore, it is possible to establish symbol synchronization by detecting timing at which the accumulation result exceeds the threshold.

Thus, the accumulation result, which is the output of accumulation section 110, is sent to subtractor 111 to be subjected to a subtraction from a predetermined threshold and the subtraction result is sent to determination section 112 to judge which is larger or smaller. This allows threshold judgment and timing that exceeds the threshold can be regarded as the FFT processing start timing in FFT section 113. In this way, timing is provided so that FFT is started by establishing symbol synchronization between the transmitting side and receiving side.

As shown in FIG.6, in the present embodiment, 0 symbol 203 is inserted after phase reference symbol 202 in a signal frame. Therefore, under circumstances under which tens of delay signals are received, if signals with high signal power are included, correlation processing is carried out between the 0 symbol of the reception signal and the phase reference symbol when a correlation is found between the reception signal and the signal delayed by one symbol. In this case, since correlation processing is performed with the 0 symbol, the

correlation result becomes very small no matter how high the signal power may be. For this reason, a peak exceeding a threshold is identified near the FFT processing start timing, thus making it possible to  
5 accurately detect the FFT processing start timing.

The A/D-converted baseband signal is subjected to FFT processing at the FFT processing start timing above in FFT section 113 to obtain signals assigned to their respective subcarriers. These signals are sent to  
10 demodulation section 114, subjected to delay detection processing, compared with the signal one bit ahead by determination section 115 to become a demodulated signal.

As shown above, since the OFDM communication apparatus of the present embodiment has the 0 symbol inserted immediately after the phase reference symbol used for delay detection, making it possible to reduce correlation output near the synchronization timing position. Therefore, the OFDM communication apparatus  
20 of the present embodiment can suppress a correlation value exceeding a threshold even if signals with high power are included. As a result, the OFDM communication apparatus of the present embodiment can accurately detect FFT processing start timing and prevent  
25 desynchronization.

(Embodiment 2)

The present embodiment explains a case where a 0

signal of an interval shorter than the phase reference symbol cycle is inserted immediately after the phase reference symbol.

FIG.7 is a block diagram showing a configuration 5 of the OFDM communication apparatus according to Embodiment 2 of the present invention. In FIG.7, the same parts as those in FIG.5 are assigned the same codes as those in FIG. 5 and their detailed explanations are omitted.

10 In the OFDM communication apparatus shown in FIG.7, the transmission section carries out IFFT processing on a signal with a synchronization symbol inserted, inserts a guard interval and then inserts a 0 signal. Therefore, 0 symbol insertion section 103 is removed and 0 signal 15 insertion section 301 is provided after guard interval insertion section 105.

Then, the operation of the OFDM communication apparatus with the above configuration is explained using FIG.7 and FIG.8. Synchronization symbol 201 is 20 inserted by synchronization symbol insertion section 102 into the signal digital-modulated by modulation section 101 as in the case of Embodiment 1. Phase reference symbol 202 is inserted after synchronization symbol 201. This phase reference symbol 202 is identical to 25 synchronization symbol 201. This phase reference symbol 202 is inserted by synchronization symbol insertion section 102 in like manner.

The signal with synchronization symbol 201

inserted is sent to IFFT section 104 and subjected to an IFFT calculation. Then, guard interval 204 is inserted into the IFFT-transformed signal waveform by guard interval insertion section 105.

5       Then, a 0 signal, which is a correlation value suppression signal, is inserted into the signal with the guard interval inserted by 0 signal insertion section 301. This 0 signal insertion section 301 is made up of a switch and when control signal 3 instructing 0 signal 10 401 to be inserted is input, this switch is switched to insert 0 signal 401. The interval of this 0 signal 401 is set to be shorter than the cycle of phase reference symbol 202. For example, it is preferable to set the interval to approximately 1/4 symbol. This minimizes 15 the interval during which signals without power are sent.

Then, the signal with such a 0 signal inserted is D/A-converted by D/A converter 106. Then, the D/A-converted signal is subjected to normal radio transmission processing and then transmitted. That is, 20 the above signal is frequency-converted and amplified by a radio transmission section, which is not shown in the figure, and transmitted from an antenna.

On the other hand, a signal received from an antenna is subjected to normal radio reception processing. For 25 the baseband signal, symbol synchronization is established using a guard interval as in the case of Embodiment 1.

As shown in FIG.8, the present embodiment has 0

signal 401 inserted after phase reference symbol 202 in a signal frame. Therefore, under circumstances under which tens of delay signals are received, if signals with high signal power are included, correlation processing 5 is carried out between the 0 signal of the reception signal and the phase reference symbol when a correlation is found between the reception signal and the signal delayed by one symbol. In this case, since correlation processing is performed with the 0 signal, the 10 correlation result becomes very small no matter how high the signal power may be. For this reason, a peak exceeding a threshold is identified near the FFT processing start timing, thus making it possible to accurately detect the FFT processing start timing.

15       The A/D-converted baseband signal is subjected to FFT processing at the FFT processing start timing above in FFT section 113 to obtain signals assigned to their respective subcarriers. These signals are sent to demodulation section 114, subjected to delay detection 20 processing, compared with the signal one bit ahead by determination section 115 to become a demodulated signal.

As shown above, since the OFDM communication apparatus of the present embodiment has the 0 signal 25 inserted immediately after the phase reference symbol used for delay detection, making it possible to reduce correlation output near the synchronization timing position. Therefore, the OFDM communication apparatus

of the present embodiment can suppress a correlation value exceeding a threshold even if signals with high power are included. As a result, the OFDM communication apparatus the present embodiment can accurately detect  
5 FFT processing start timing and prevent desynchronization. Furthermore, since the 0 signal inserted immediately after the phase reference symbol is shorter than the phase reference symbol cycle, thus minimizing the interval during which signals without  
10 power are sent.

## (Embodiment 3)

The present embodiment explains a case where reception level information is used for symbol  
15 synchronization acquisition.

FIG.9 is a block diagram showing a configuration of the OFDM communication apparatus according to Embodiment 3 of the present invention. In FIG.9, the same parts as those in FIG.7 are assigned the same codes  
20 as those in FIG.7 and their detailed explanations are omitted.

In the OFDM communication apparatus shown in FIG.9, the reception section comprises level detection section 501 that detects the reception level of a baseband signal,  
25 subtraction section 502 that compares the detected level with a predetermined threshold, determination section 503 that judges which is larger or smaller based on the subtraction result and AND section 504 that calculates

AND between the determination result of determination section 503 and the determination result for FFT processing start timing detection.

Then, the operation of the OFDM communication apparatus with the above configuration is explained using FIG.9.

The operation on the transmitting side is the same as that in Embodiment 2. Therefore, a signal to be transmitted has a frame configuration as shown in FIG.8.

On the other hand, a signal received from an antenna is subjected to normal radio reception processing. For a baseband signal, symbol synchronization is established using a guard interval in the same way as for Embodiment 1.

In the present embodiment, a baseband signal is sent to level detection section 501 to be subjected to level detection and that level is sent to level subtraction section 502 to be subjected to a subtraction with a predetermined threshold. This subtraction result is sent to determination section 503 and judged which is larger or smaller. That is, the detected level is subjected to threshold judgment.

Moreover, as in the case of Embodiment 2, the result of a correlation between the reception signal and the signal delayed by one symbol is subjected to threshold judgment. The result of threshold judgment of the above level and the result of threshold judgment of the correlation are sent to AND section 504 and the AND

information is sent to FFT section 113. That is, the timing at which the detected level is lower than the threshold in the threshold judgment of level detection and the correlation result is higher than the threshold  
5 in the threshold judgment of the correlation result becomes the FFT processing start timing.

The A/D-converted baseband signal is subjected to FFT processing at the FFT processing start timing above in FFT section 113 to obtain signals assigned to their  
10 respective subcarriers. These signals are further sent to demodulation section 114 to be subjected to delay detection processing, compared with the signal one bit ahead by determination section 115 to become a demodulated signal.

15 As shown above, the OFDM communication apparatus of the present embodiment can suppress a correlation value exceeding a threshold even if signals with high power are included, accurately detect the FFT processing start timing and prevent desynchronization.  
20 Furthermore, since the 0 signal inserted immediately after the phase reference symbol is shorter than the phase reference symbol cycle, thus minimizing the interval during which signals without power are sent. Furthermore, the OFDM communication apparatus of the  
25 present embodiment performs level detection of the reception signal, and therefore can accurately detect the signal with a high correlation result and more accurately detect the FFT processing start timing.

## (Embodiment 4)

The present embodiment explains a case where the interval into which a 0 signal is inserted is made  
5 variable.

FIG.10 is a block diagram showing a configuration  
of the OFDM communication apparatus according to  
Embodiment 4 of the present invention. In FIG.10, the  
same parts as those in FIG.7 are assigned the same codes  
10 as those in FIG.7 and their detailed explanations are  
omitted.

The OFDM communication apparatus shown in FIG.10  
includes first subtraction section 605 that calculates  
a difference between signals before and after judgment  
15 by determination section 115, second subtraction section  
604 that calculates a difference between this  
subtraction result and a predetermined threshold,  
determination section 603 that judges whether the  
subtraction result of the second subtraction section is  
20 larger or smaller, switch 602 that selects whether or  
not to insert a 0 signal according to this determination  
result and 0 signal insertion section 601 that inserts  
a 0 signal immediately after the phase reference symbol.

0 signal insertion section 601 is made up of a switch  
25 and when control signal 3 instructing a 0 signal to be  
inserted is input to switch 602, this switch is switched  
to insert the 0 signal. Switch 602 is switched through  
control signal 3 instructing the 0 signal to be inserted

and control signal 4 instructing the 0 signal not to be inserted according to the judgment result of determination section 603.

Then, the operation of the OFDM communication apparatus with the above configuration is explained using FIG.10. Synchronization symbol 201 is inserted by synchronization symbol insertion section 102 into the signal digital-modulated by modulation section 101 as in the case of Embodiment 1. Phase reference symbol 202 is inserted after synchronization symbol 201.

The signal with synchronization symbol 201 inserted is sent to IFFT section 104 and subjected to an IFFT calculation. Then, guard interval 204 is inserted into the IFFT-transformed signal waveform by guard interval insertion section 105.

On the other hand, a signal received from an antenna is subjected to normal radio reception processing. For the baseband signal, symbol synchronization is established using a guard interval as in the case of Embodiment 1.

As shown in FIG.8, 0 signal 401 is inserted after phase reference symbol 202 in a signal frame. Therefore, correlation processing is carried out between the 0 signal of the reception signal and the phase reference symbol when a correlation is found between the reception signal and the signal delayed by one symbol.

The A/D-converted baseband signal is subjected to FFT processing at the FFT processing start timing above

in FFT section 113 to obtain signals assigned to their respective subcarriers. These signals are sent to demodulation section 114 to be subjected to delay detection processing, compared with the signal one bit ahead by determination section 115 to become a demodulated signal.

In the case above, signals before and after judgment are sent to first subtraction section 605 where the difference between the two signals is found. This difference is sent to second subtraction section 604 and compared with a threshold. This comparison result is judged by determination section 603. If the difference is larger than this threshold, determination section 603 judges that the communication environment is ill conditioned, that is, the interval of the 0 signal is short and controls so as to lengthen the interval of the 0 signal.

More specifically, to lengthen the interval of the 0 signal, control signal 3 is input to switch 602 so that switch 602 is switched and the 0 signal is inserted by 0 signal insertion section 601. On the other hand, if there is no need to lengthen the 0 signal, control signal 4 is input to switch 602 so that switch 602 is switched preventing 0 signal insertion section 601 from inserting the 0 signal. Thus, it is possible to adaptively change the interval of the 0 signal in the signal frame.

Then, the signal with the 0 signal inserted in this way is D/A-converted by D/A converter 106. Then, the

D/A-converted signal is subjected to normal radio transmission processing and then transmitted. That is, the above signal is frequency-converted and amplified by a radio transmission section, which is not shown in 5 the figure, and transmitted from an antenna.

As shown above, the OFDM communication apparatus of the present embodiment inserts the 0 signal immediately after the phase reference symbol used for delay detection, reducing the correlation output near 10 the synchronization timing position, making it possible to accurately detect the FFT processing start timing and prevent desynchronization. Furthermore, the OFDM communication apparatus of the present embodiment can switch whether or not to insert the 0 signal, making it 15 possible to adaptively change the interval of the 0 signal in a signal frame and flexibly respond to the communication environment.

(Embodiment 5)

20 The present embodiment explains a case where a phase reference symbol whose polarity is inverted, which is a correlation value suppression symbol, is inserted immediately after the phase reference symbol.

FIG.11 is a block diagram showing a configuration 25 of the OFDM communication apparatus according to Embodiment 5 of the present invention. In FIG.11, the same parts as those in FIG.5 are assigned the same codes as those in FIG.5 and their detailed explanations are

omitted.

In the OFDM communication apparatus shown in FIG.11, the transmission section inserts an inverted symbol for the signal with a synchronization symbol inserted.

- 5 Therefore, instead of 0 symbol insertion section 102, inverted symbol insertion section 701 is provided. This inverted symbol insertion section 701 is made up of a switch and when control signal 2 instructing the inverted symbol to be inserted is input, this switch is switched  
10 to insert the inverted symbol.

Then, the operation of the OFDM communication apparatus with the above configuration is explained using FIG.11 and FIG.12. Synchronization symbol 201 is inserted by synchronization symbol insertion section 102  
15 into the signal digital-modulated by modulation section 101 as in the case of Embodiment 1. Phase reference symbol 202 is inserted after synchronization symbol 201. This phase reference symbol 202 is identical to synchronization symbol 201. This phase reference  
20 symbol 202 is inserted by synchronization symbol insertion section 102 in like manner.

Inverted symbol 801, which is the phase reference symbol inverted by inverted symbol insertion section 701, is inserted into the signal with synchronization symbol 201 inserted. The signal with these symbols inserted is sent to IFFT section 104 to be subjected to an IFFT calculation. Then, guard interval 204 is inserted into the IFFT-transformed signal waveform by guard interval

insertion section 105.

Then, the signal with guard interval 204 inserted is D/A-converted by D/A converter 106. Then, the D/A-converted signal is subjected to normal radio 5 transmission processing and transmitted. That is, the above signal is frequency-converted and amplified by a radio transmission section, which is not shown in the figure, and transmitted from an antenna.

On the other hand, a signal received from an antenna 10 is subjected to normal radio reception processing. For the baseband signal, symbol synchronization is established using a guard interval as in the case of Embodiment 1.

As shown in FIG.12, the present embodiment has 15 inverted symbol 801 inserted after phase reference symbol 202 in a signal frame. Therefore, under circumstances under which tens of delay signals are received, if signals with high signal power are included, correlation processing is carried out between the 20 inverted symbol of the reception signal and the phase reference symbol when a correlation is found between the reception signal and the signal delayed by one symbol. In this case, since correlation processing is performed 25 with the inverted symbol, both symbols are canceled out and the correlation result becomes very small no matter how high the signal power may be. For this reason, a peak exceeding a threshold is identified near the FFT processing start timing, thus making it possible to

accurately detect the FFT processing start timing.

The A/D-converted baseband signal is subjected to FFT processing at the FFT processing start timing above in FFT section 113 to obtain signals assigned to their respective subcarriers. These signals are further sent to demodulation section 114, subjected to delay detection processing and compared with the signal one bit ahead by determination section 115 to become a demodulated signal.

As shown above, since the OFDM communication apparatus of the present embodiment has the inverted symbol, which is the inverted phase reference symbol, inserted immediately after the phase reference symbol used for delay detection, making it possible to cancel out and reduce correlation output near the synchronization timing position. Therefore, the OFDM communication apparatus of the present embodiment can suppress a correlation value exceeding a threshold even if signals with high power are included. As a result, the OFDM communication apparatus of the present embodiment can accurately detect FFT processing start timing and prevent desynchronization.

(Embodiment 6)

The present embodiment explains a case where an inverted signal of a shorter interval than the cycle of the phase reference symbol is inserted immediately after the phase reference symbol.

FIG.13 is a block diagram showing a configuration of the OFDM communication apparatus according to Embodiment 6 of the present invention. In FIG.13, the same parts as those in FIG.11 are assigned the same codes 5 as those in FIG.11 and their detailed explanations are omitted.

In the OFDM communication apparatus shown in FIG.13, the transmission section carries out IFFT processing on the signal with a synchronization symbol inserted and 10 inserts a guard interval and then inserts an inverted signal. Therefore, inverted symbol insertion section 701 is removed and inverted signal insertion section 901 is provided after guard interval insertion section 105.

Then, the operation of the OFDM communication 15 apparatus with the above configuration is explained using FIG.13 and FIG.14. Synchronization symbol 201 is inserted by synchronization symbol insertion section 102 into the signal digital-modulated by modulation section 101 as in the case of Embodiment 1. Phase reference 20 symbol 202 is inserted after synchronization symbol 201. This phase reference symbol 202 is identical to synchronization symbol 201. This phase reference symbol 202 is inserted by synchronization symbol insertion section 102 in like manner.

25 The signal with synchronization symbol 201 inserted is sent to IFFT section 104 to be subjected to an IFFT calculation. Then, guard interval 204 is inserted into the IFFT-transformed signal waveform by

guard interval insertion section 105.

Then, an inverted signal, which is a correlation value suppression signal, is inserted into the signal with the guard interval inserted by inverted signal 5 insertion section 901. This inverted signal insertion section 901 is made up of a switch and when control signal 3 instructing inverted signal 1001 to be inserted is input, this switch is switched to insert inverted signal 1001. The interval of this inverted signal 1001 is set 10 to be shorter than the cycle of phase reference symbol 202. For example, it is preferable to set the interval to approximately 1/4 symbol. This minimizes the interval during which signals without power are sent.

Then, the signal with such an inverted signal 15 inserted is D/A-converted by D/A converter 106. Then, the D/A-converted signal is subjected to normal transmission processing and then transmitted. That is, the above signal is frequency-converted and amplified by a radio transmission section, which is not shown in 20 the figure, and transmitted from an antenna.

On the other hand, a signal received from an antenna is subjected to normal radio reception processing. For the baseband signal, symbol synchronization is established using a guard interval as in the case of

25 Embodiment 1.

As shown in FIG.14, the present embodiment has inverted signal 1001 inserted after phase reference symbol 202 in a signal frame. Therefore, under

circumstances under which tens of delay signals are received, if signals with high signal power are included, correlation processing is carried out between the inverted signal of the reception signal and the phase reference symbol when a correlation is found between the reception signal and the signal delayed by one symbol. In this case, since correlation processing is performed with the inverted signal, both signals cancel out each other and the correlation result becomes very small no matter how high the signal power may be. For this reason, a peak exceeding a threshold is identified near the FFT processing start timing, thus making it possible to accurately detect the FFT processing start timing.

The A/D-converted baseband signal is subjected to  
15 FFT processing at the FFT processing start timing above  
in FFT section 113 to obtain signals assigned to their  
respective subcarriers. These signals are further sent  
to demodulation section 114, subjected to delay  
detection processing, and compared with the signal one  
20 bit ahead by determination section 115 to become a  
demodulated signal.

As shown above, since the OFDM communication apparatus of the present embodiment has the inverted signal inserted immediately after the phase reference symbol used for delay detection, making it possible to reduce correlation output near the synchronization timing position. Therefore, the OFDM communication apparatus of the present embodiment can suppress a

correlation value exceeding a threshold even if signals with high power are included. As a result, the OFDM communication apparatus of the present embodiment can accurately detect FFT processing start timing and 5 prevent desynchronization. Furthermore, since the inverted signal inserted immediately after the phase reference symbol is shorter than the phase reference symbol cycle, thus minimizing the interval during which signals without power are sent.

10

## (Embodiment 7)

The present embodiment explains a case where the interval into which an inverted signal is inserted is made variable.

15

FIG.15 is a block diagram showing a configuration of the OFDM communication apparatus according to Embodiment 7 of the present invention. In FIG.15, the same parts as those in FIG.10 are assigned the same codes as those in FIG.10 and their detailed explanations are 20 omitted.

20

The OFDM communication apparatus shown in FIG.15 includes first subtraction section 1105 that calculates a difference between signals before and after judgment by determination section 1105, second subtraction section 25 1104 that calculates a difference between this subtraction result and a predetermined threshold, determination section 1103 that judges whether the subtraction result of the second subtraction section is

larger or smaller, switch 1102 that selects whether or not to insert an inverted signal according to this determination result and inverted signal insertion section 1101 that inserts an inverted signal immediately after the phase reference symbol.

- Inverted signal insertion section 1101 is made up of a switch and when control signal 3 instructing an inverted signal to be inserted is input to switch 1102, this switch is switched to insert the inverted signal.
- 10 Switch 1102 is switched through control signal 3 instructing the inverted signal to be inserted and control signal 4 instructing the inverted signal not to be inserted according to the judgment result of determination section 1103.

15 Then, the operation of the OFDM communication apparatus with the above configuration is explained using FIG.15. Synchronization symbol 201 is inserted by synchronization symbol insertion section 102 into the signal digital-modulated by modulation section 101 as 20 in the case of Embodiment 1. Phase reference symbol 202 is inserted after synchronization symbol 201.

The signal with synchronization symbol 201 inserted is sent to IFFT section 104 and subjected to an IFFT calculation. Then, guard interval 204 is 25 inserted into the IFFT-transformed signal waveform by guard interval insertion section 105.

On the other hand, a signal received from an antenna is subjected to normal radio reception processing. For

the baseband signal, symbol synchronization is established using a guard interval as in the case of Embodiment 1.

As shown in FIG.14, the present embodiment has 5 inverted signal 1101 inserted after phase reference symbol 202 in a signal frame. Therefore, correlation processing is carried out between the inverted signal of the reception signal and the phase reference symbol when a correlation is found between the reception signal 10 and the signal delayed by one symbol.

The A/D-converted baseband signal is subjected to FFT processing at the FFT processing start timing above in FFT section 113 to obtain signals assigned to their respective subcarriers. These signals are sent to 15 demodulation section 114, subjected to delay detection processing and compared with the signal one bit ahead by determination section 115 to become a demodulated signal.

In the case above, signals before and after judgment 20 are sent to first subtraction section 1105 where the difference between the two signals is found. This difference is sent to second subtraction section 1104 and compared with a threshold. This comparison result is judged by determination section 1103. If the 25 difference is larger than this threshold, determination section 1103 judges that the communication environment is ill conditioned, that is, the interval of the inverted signal is short and controls so as to lengthen the

interval of the inverted signal.

More specifically, to lengthen the interval of the inverted signal, control signal 3 is input to switch 1102 so that switch 1102 is switched and the inverted signal 5 is inserted by inverted signal insertion section 1101. On the other hand, if there is no need to lengthen the inverted signal, control signal 4 is input to switch 1102 so that switch 1102 is switched preventing inverted signal insertion section 1101 from inserting the 10 inverted signal. Thus, it is possible to adaptively change the interval of the inverted signal in the signal frame.

Then, the signal with the inverted signal inserted is D/A-converted by D/A converter 106. Then, the 15 D/A-converted signal is subjected to normal radio transmission processing and then transmitted. That is, the above signal is frequency-converted and amplified by a radio transmission section, which is not shown in the figure, and transmitted from an antenna.

20 As shown above, the OFDM communication apparatus of the present embodiment inserts the inverted signal immediately after the phase reference symbol used for delay detection, reducing the correlation output near the synchronization timing position, making it possible 25 to accurately detect the FFT processing start timing and prevent desynchronization. Furthermore, the OFDM communication apparatus of the present embodiment can switch whether or not to insert the inverted signal,

making it possible to adaptively change the interval of the inverted signal in a signal frame and flexibly adapt to the communication environment.

5 (Embodiment 8)

The present embodiment explains a case where the level of an inverted signal inserted immediately after the phase reference symbol is increased.

FIG.16 is a block diagram showing a configuration 10 of the OFDM communication apparatus according to Embodiment 8 of the present invention. In FIG.16, the same parts as those in FIG.13 are assigned the same codes as those in FIG.13 and their detailed explanations are omitted.

15 In the OFDM communication apparatus shown in FIG.16, the transmission section carries out IFFT processing on the signal with a synchronization symbol inserted and inserts a guard interval and then inserts an inverted signal. At this time, gain section 1201 is provided to 20 increase the level of the inverted signal.

Then, the operation of the OFDM communication apparatus with the above configuration is explained using FIG.16. Synchronization symbol 201 is inserted by synchronization symbol insertion section 102 into the 25 signal digital-modulated by modulation section 101 as in the case of Embodiment 1. Phase reference symbol 202 is inserted after synchronization symbol 201. This phase reference symbol 202 is identical to

synchronization symbol 201. This phase reference symbol 202 is inserted by synchronization symbol insertion section 102 in like manner.

The signal with synchronization symbol 201  
5 inserted is sent to IFFT section 104 to be subjected to an IFFT calculation. Then, guard interval 204 is inserted into the IFFT-transformed signal waveform by guard interval insertion section 105.

Then, an inverted signal is inserted into the signal  
10 with the guard interval inserted by inverted signal insertion section 901. The level of this inverted signal is increased by gain section 1201. The gain level is set according to the communication environment and the number of delay signals, etc. as appropriate.

15 Then, the signal with such an inverted signal inserted is D/A-converted by D/A converter 106. Then, the D/A-converted signal is subjected to normal transmission processing and then transmitted. That is, the above signal is frequency-converted and amplified  
20 by a radio transmission section, which is not shown in the figure, and transmitted from an antenna.

On the other hand, a signal received from an antenna is subjected to normal radio reception processing. For the baseband signal, symbol synchronization is  
25 established using a guard interval as in the case of Embodiment 1.

As shown in FIG.14, the present embodiment has inverted signal 1001 inserted after phase reference

symbol 202 in a signal frame. Therefore, under circumstances under which tens of delay signals are received, if signals with high signal power are included, correlation processing is carried out between the 5 inverted signal of the reception signal and the phase reference symbol when a correlation is found between the reception signal and the signal delayed by one symbol. In this case, since the level of the inverted signal is increased, both signals cancel out each other and the 10 correlation result becomes very small no matter how high the signal power may be. For this reason, a peak exceeding a threshold is identified near the FFT processing start timing, thus making it possible to accurately detect the FFT processing start timing.

15       The A/D-converted baseband signal is subjected to FFT processing at the FFT processing start timing above in FFT section 113 to obtain signals assigned to their respective subcarriers. These signals are further sent to demodulation section 114, subjected to delay 20 detection processing and compared with the signal one bit ahead by determination section 115 to become a demodulated signal.

As shown above, since the OFDM communication apparatus of the present embodiment has an inverted 25 signal with high gain inserted immediately after the phase reference symbol used for delay detection, making it possible to reduce correlation output near the synchronization timing position. Therefore, the OFDM

communication apparatus of the present embodiment can suppress a correlation value exceeding a threshold even if signals with high power are included. As a result, the OFDM communication apparatus of the present embodiment can accurately detect FFT processing start timing and prevent desynchronization.

(Embodiment 9)

The present embodiment explains a case where the gain of an inverted signal is made variable.

FIG.17 is a block diagram showing a configuration of the OFDM communication apparatus according to Embodiment 9 of the present invention. In FIG.17, the same parts as those in FIG.15 are assigned the same codes as those in FIG.15 and their detailed explanations are omitted.

The OFDM communication apparatus shown in FIG.17 includes first subtraction section 1105 that calculates a difference between signals before and after judgment by determination section 1105, second subtraction section 1104 that calculates a difference between this subtraction result and a predetermined threshold, determination section 1103 that judges whether the subtraction result of the second subtraction section is larger or smaller, switch 1302 that changes the gain of the inverted signal according to this determination result, inverted signal insertion section 1301 that inserts an inverted signal immediately after the phase

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reference symbol and gain section 1201 that changes the level of the inverted signal.

Inverted signal insertion section 1301 is made up of a switch and when control signal 3 instructing an 5 inverted signal to be inserted is input, this switch is switched to insert the inverted signal. Switch 1302 changes the gain of the inverted signal based on the determination result of determination section 1103.

Then, the operation of the OFDM communication 10 apparatus with the above configuration is explained using FIG.17. Synchronization symbol 201 is inserted by synchronization symbol insertion section 102 into the signal digital-modulated by modulation section 101 as in the case of Embodiment 1. Phase reference symbol 202 15 is inserted after synchronization symbol 201.

The signal with synchronization symbol 201 inserted is sent to IFFT section 104 and subjected to an IFFT calculation. Then, guard interval 204 is inserted into the IFFT-transformed signal waveform by 20 guard interval insertion section 105.

On the other hand, a signal received from an antenna is subjected to normal radio reception processing. For the baseband signal, symbol synchronization is established using a guard interval as in the case of 25 Embodiment 1.

As shown in FIG.14, the present embodiment has inverted signal 1001 inserted after phase reference symbol 202 in a signal frame. Therefore, correlation

processing is carried out between the inverted signal of the reception signal and the phase reference symbol when a correlation is found between the reception signal and the signal delayed by one symbol.

- 5       The A/D-converted baseband signal is subjected to FFT processing at the FFT processing start timing above in FFT section 113 to obtain signals assigned to their respective subcarriers. These signals are sent to demodulation section 114, subjected to delay detection  
10 processing and compared with the signal one bit ahead by determination section 115 to become a demodulated signal.

In the case above, signals before and after judgment are sent to first subtraction section 1105 where the  
15 difference between the two signals is found. This difference is sent to second subtraction section 1104 and compared with a threshold. This comparison result is judged by determination section 1103. If the difference is larger than this threshold, determination  
20 section 1103 judges that the communication environment is ill conditioned, that is, the level of the inverted signal is low and controls so as to increase the level of the inverted signal.

More specifically, to increase the level of the  
25 inverted signal, switch 1302 is switched to send the inverted signal whose level has been increased by gain section 1201 to inverted signal insertion section 1301 and insert a high level inverted signal there. On the

other hand, if there is no need to increase the level of the inverted signal, switch 1302 is switched to send the inverted signal of that level to inverted signal insertion section 1301 and insert the inverted signal 5 there. In this way, the level of the inverted signal can be changed adaptively in a signal frame.

Then, the signal with the inverted signal inserted in this way is D/C-converted by D/A conversion section 106. Then, the D/A-converted signal is subjected to 10 normal radio transmission processing and then transmitted. That is, the signal above is frequency-converted and amplified by a radio transmission section, which is not shown in the figure, and transmitted from an antenna.

15 As shown above, the OFDM communication apparatus of the present embodiment has an inverted signal inserted immediately after the phase reference symbol used for delay detection making it possible to reduce correlation output near the synchronization timing position, 20 accurately detect FFT processing start timing and prevent desynchronization. Moreover, the OFDM communication apparatus of the present embodiment can adaptively make the level of the inverted signal variable by switching between the levels of the inverted signal, 25 thus flexibly responding to the communication environment.

The present embodiment explains a case where the gain of an inverted signal is made variable using average reception quality information.

FIG.18 is a block diagram showing a configuration  
5 of the OFDM communication apparatus according to  
Embodiment 10 of the present invention. In FIG.18, the  
same parts as those in FIG.17 are assigned the same codes  
as those in FIG.17 and their detailed explanations are  
omitted.

10 The OFDM communication apparatus shown in FIG.18  
includes averaging section 1401 that calculates a burst  
average of the subtraction result of first subtraction  
section 1105 that calculates a difference between  
signals before and after judgment in determination  
15 section 115.

This averaging section 1401 averages bursts of  
first subtraction section 1105 preventing the gain of  
the inverted signal from being increased when a threshold  
is exceeded suddenly. This allows interference with  
20 others to be reduced.

Then, the operation of the OFDM communication  
apparatus with the above configuration is explained  
using FIG.18. Synchronization symbol 201 is inserted by  
synchronization symbol insertion section 102 into the  
25 signal digital-modulated by modulation section 101 as  
in the case of Embodiment 1. Phase reference symbol 202  
is inserted after synchronization symbol 201.

The signal with synchronization symbol 201

inserted is sent to IFFT section 104 and subjected to an IFFT calculation. Then, guard interval 204 is inserted into the IFFT-transformed signal waveform by guard interval insertion section 105.

5 On the other hand, a signal received from an antenna is subjected to normal radio reception processing. For the baseband signal, symbol synchronization is established using a guard interval as in the case of Embodiment 1.

10 As shown in FIG.14, the present embodiment has inverted signal 1001 inserted after phase reference symbol 202 in a signal frame. Therefore, correlation processing is carried out between the inverted signal of the reception signal and the phase reference symbol  
15 when a correlation is found between the reception signal and the signal delayed by one symbol.

The A/D-converted baseband signal is subjected to FFT processing at the FFT processing start timing above in FFT section 113 to obtain signals assigned to their respective subcarriers. These signals are further sent to demodulation section 114, subjected to delay detection processing and compared with the signal one bit ahead by determination section 115 to become a demodulated signal.

25 In the case above, signals before and after judgment are sent to first subtraction section 1105 where the difference between the two signals is found. This difference is sent to averaging section 1401 where a

burst average is calculated. This averaging result is sent to second subtraction section 1104 and compared with a threshold. This comparison result is judged by determination section 1103. If the difference is larger than this threshold, determination section 1103 judges that the communication environment is ill conditioned, that is, the level of the inverted signal is low and controls so as to increase the level of the inverted signal.

More specifically, to increase the level of the inverted signal, switch 1302 is switched to send the inverted signal whose level has been increased by gain section 1201 to inverted signal insertion section 1301 and the high-level inverted signal is inserted there. On the other hand, if there is no need to increase the level of the inverted signal, switch 1302 is switched to send the inverted signal of the same level to inverted signal insertion section 1301 and insert the inverted signal there. Thus, it is possible to adaptively make the level of the inverted signal variable in the signal frame.

Then, the signal with the inverted signal inserted in this way is D/A-converted by D/A converter 106. Then, the D/A-converted signal is subjected to normal radio transmission processing and then transmitted. That is, the above signal is frequency-converted and amplified by a radio transmission section, which is not shown in the figure, and transmitted from an antenna.

As shown above, the OFDM communication apparatus of the present embodiment has an inverted signal inserted immediately after the phase reference symbol used for delay detection making it possible to reduce correlation 5 output near the synchronization timing position, accurately detect FFT processing start timing and prevent desynchronization. Moreover, the OFDM communication apparatus of the present embodiment can adaptively make the level of the inverted signal variable 10 by switching between the levels of the inverted signal, thus flexibly responding to the communication environment. In this case, since bursts of first subtraction section 1105 are averaged, it is possible to prevent the gain of the inverted signal from being 15 increased when a threshold is exceeded suddenly. This allows interference with others to be reduced.

(Embodiment 11)

The present embodiment explains a case where a 20 synchronization pull-in method, which is different from the above described embodiments, is used with reference to FIG.19. As the synchronization pull-in method, in addition to a method of detecting a maximum value of the result of a correlation between the reception signal and 25 this reception signal delayed by one symbol (the method in the above embodiments), there is another method of detecting a maximum value of the result of a correlation between a signal with an IFFT-processed phase reference

symbol (pilot symbol) and the reception signal. The OFDM communication apparatus of the present embodiment uses this synchronization pull-in method. Here, a case where this synchronization pull-in method is used in the OFDM 5 communication apparatus according to Embodiment 1 is explained as an example.

FIG.19 is a block diagram showing a configuration of the OFDM communication apparatus according to Embodiment 11 of the present invention. In FIG.19, the 10 same parts as those in FIG.5 are assigned the same codes as those in FIG.5 and their detailed explanations are omitted.

In the OFDM communication apparatus shown in FIG.19, the reception section includes correlator 1501 that 15 calculates a correlation between the signal with an IFFT-processed phase reference symbol (pilot symbol) and the reception signal. The internal configuration of this correlator 1501 is explained using FIG.20.

FIG.20 is a block diagram showing the internal 20 configuration of correlator 1501 in the OFDM communication apparatus according to Embodiment 11. As shown in FIG.20, the signal output from A/D converter 107 (reception signal) and a signal with an IFFT- processed phase reference symbol are input to correlator 25 1501. More specifically, if the number of samples in IFFT processing is n, signals at the first to nth sample points (ref1 to refn in the figure) obtained by IFFT-processing the phase reference symbol are input to

correlator 1501.

Furthermore, as shown in FIG.20, correlator 1501 includes multipliers 1601a to 1601n, delayers 1602a to 1602n and adders 1603a to 1603n. Correlator 1501 with  
5 the above configuration calculates a value of a correlation between the reception signal and the signal with an IFFT-processed phase reference symbol from adder 1603n.

The correlation value output from correlator 1501  
10 is sent to subtraction section 111 and subjected to the same processing as that explained in Embodiment 1. In this way, synchronization pull-in processing is carried out.

In the present embodiment, as shown in FIG.6, 0  
15 symbol 203 is inserted after phase reference symbol 202 in a signal frame. Therefore, under circumstances under which tens of delay signals are received and signals with high power are included, correlation processing is carried out between the 0 symbol of the reception signal  
20 and the signal with an IFFT-processed phase reference symbol when a correlation is found between the signal with an IFFT-processed phase reference symbol and the reception signal. In this case, since correlation processing is performed with the 0 symbol, the  
25 correlation result becomes very small no matter how high the signal power may be. For this reason, a peak exceeding a threshold is identified near the FFT processing start timing, thus making it possible to

accurately detect the FFT processing start timing.

As shown above, since the OFDM communication apparatus of the present embodiment has a 0 symbol inserted immediately after the phase reference symbol  
5 used for synchronization pull-in processing, making it possible to reduce correlation output near the synchronization timing position. Therefore, the OFDM communication apparatus of the present embodiment can suppress a correlation value exceeding a threshold even  
10 if signals with high power are included. As a result, the present embodiment can accurately detect FFT processing start timing and prevent desynchronization.

The present embodiment explains the case where the synchronization pull-in method above is used for the OFDM communication apparatus according to Embodiment 1, but  
15 the present invention is also applicable to cases where the synchronization pull-in method above is used for Embodiments 2 to 10.

20 (Embodiment 12)

The present embodiment explains a case where a hard decision section is used for the IFFT-processed signal instead of a multiplier in the correlator that finds a correlation between the signal with an IFFT-processed  
25 phase reference symbol and the reception signal, with reference to FIG.21.

FIG.21 is a block diagram showing a configuration of a hard decision section in the OFDM communication

apparatus according to Embodiment 12 of the present invention. The hard decision section shown in FIG.21 is provided as a substitute for each of multipliers 1601a to 1601n in the correlator shown in FIG.20. Hard 5 decision section 1701 outputs a hard decision value for the signal (reception signal) output from A/D converter 107. Selector 1702 finds a correlation between the signal from hard decision section 1701, that is, a hard decision value, and the reception signal, that is, a soft 10 decision value.

As shown above, the OFDM communication apparatus according to the present embodiment is equipped with a correlator configured without using any multiplier, and thus can drastically reduce the hardware scale.

15

## (Embodiment 13)

The present embodiment explains a case where a synchronization pull-in method, which is different from the above two methods, is used, with reference to FIG.22. 20 In addition to the synchronization pull-in method using synchronization symbol 21 and phase reference symbol 22 in the frame above shown in FIG.2, there is another synchronization pull-in method using the synchronization symbol in the frame shown in FIG.4. The 25 OFDM communication apparatus according to the present embodiment uses this synchronization pull-in method. Here, a case where this synchronization pull-in method is used in the OFDM communication apparatus according

to Embodiment 1 is explained as an example with reference to Embodiment 12 and using FIG.22.

FIG.22 is a frame diagram of a signal used in the OFDM communication apparatus according to Embodiment 13  
5 of the present invention. The frame shown in FIG.22 is the frame shown in FIG.4 with synchronization symbol 31 added immediately before the phase reference symbol 32. The OFDM communication apparatus according to the present embodiment uses a synchronization pull-in method  
10 that detects a maximum value of the result of a correlation between a signal with an IFFT-processed synchronization symbol in the frame shown in FIG.22 and the reception signal.

FIG.23 is a block diagram showing a configuration  
15 of the OFDM communication apparatus according to Embodiment 13 of the present invention. In FIG.23, the same parts as those in FIG.5 are assigned the same codes as those in FIG.5 and their detailed explanations are omitted.

20 In the transmission section, synchronization symbol insertion section 1901 inserts synchronization symbol 1801 into the signal digital-modulated by modulation section 101. This synchronization symbol insertion section 1901 is made up of a switch and when  
25 control signal 4 instructing synchronization symbol 1801 to be inserted is input, this switch is switched to insert synchronization symbol 1801.

0 symbol insertion section 103 inserts 0 symbol 1802

into the signal with synchronization symbol 1801 inserted. This 0 symbol insertion section 103 is the same as that in Embodiment 1.

Phase reference symbol insertion section 1902  
5 inserts phase reference symbol 1803 and phase reference symbol 1804 into the signal with 0 symbol 1802 inserted. This phase reference symbol insertion section 1902 is made up of a switch and when control signal 5 instructing phase reference symbol 1803 and phase reference symbol 10 1804 to be inserted is input, this switch is switched to insert phase reference symbol 1803 and phase reference symbol 1804.

The signal with synchronization symbol 1801, 0 symbol 1802 and phase reference symbols above inserted 15 is sent to IFFT section 104 and subjected to an IFFT calculation.

In the reception section, the signal (reception signal) output from A/D converter 107 is sent to FFT section 113 and correlator 1903. Correlator 1903 20 calculates a correlation value between the reception signal and a signal with an IFFT-processed synchronization symbol. This correlator 1903 is different from correlator 1501 in Embodiment 12 in that a signal with an IFFT-processed synchronization symbol 25 is input instead of a signal with an IFFT-processed phase reference symbol.

The correlation value output from correlator 1903 is sent to subtraction section 111 and subjected to the

same processing as that explained in Embodiment 1. In this way, synchronization pull-in processing is performed.

As shown in FIG.6, the present embodiment has 0 symbol 1802 inserted after synchronization symbol 1801 in a signal frame. Therefore, under circumstances under which tens of delay signals are received, if signals with high signal power are included, correlation processing is carried out between the 0 symbol of the reception signal and a signal with an IFFT-processed synchronization symbol when a correlation is found between the signal with an IFFT-processed synchronization symbol and the reception signal. In this case, since correlation processing is performed with the 0 symbol, the correlation result becomes very small no matter how high the signal power may be. For this reason, a peak exceeding a threshold is identified near the FFT processing start timing, thus making it possible to accurately detect the FFT processing start timing.

As shown above, since the OFDM communication apparatus of the present embodiment has the 0 symbol inserted immediately after a synchronization symbol used for synchronization pull-in processing, making it possible to reduce correlation output near the synchronization timing position. Therefore, the OFDM communication apparatus of the present embodiment can suppress a correlation value exceeding a threshold even

if signals with high power are included. As a result, the OFDM communication apparatus of the present embodiment can accurately detect FFT processing start timing and prevent desynchronization.

5       The OFDM communication apparatus according to the present embodiment can reduce processing delays more than the OFDM communication apparatuses according to Embodiments 1 to 12 above.

That is, with the OFDM communication apparatuses  
10 according to Embodiments 1 to 12, since synchronization pull-in is carried out using synchronization symbol 201 and phase reference symbol 202, synchronization is established immediately after phase reference symbol 202 if there is no synchronization error. However, since  
15 synchronization symbol 201 or phase reference symbol 202 is used to estimate the transmission path, these symbols need to be stored in memory. Thus, a delay is generated by one symbol or two symbols corresponding to synchronization symbol 201 or phase reference symbol  
20. 202.

On the other hand, with the OFDM communication apparatus according to the present embodiment, synchronization pull-in is performed using synchronization symbol 1801, synchronization is  
25 established immediately after synchronization symbol 1801 if there is no synchronization error. Therefore, the OFDM communication apparatus according to the present embodiment need not store the phase reference

symbol, etc. in memory as in the case of Embodiments 1 to 12, and thus can reduce the processing delay.

The present embodiment explains the case where the synchronization pull-in method is used for the OFDM communication apparatus according to Embodiment 1, but the present invention is also applicable to cases where the synchronization pull-in method above is used for Embodiments 2 to 10.

10 (Embodiment 14)

The present embodiment explains a case where a synchronization pull-in method, which is different from the above three methods, is used. As the synchronization pull-in method using synchronization symbols in the frame shown in FIG.4, there is another method of detecting a maximum value of the result of correlation between the reception signal and this reception signal delayed as appropriate in addition to the method explained in Embodiment 13. The OFDM communication apparatus according to the present embodiment uses this synchronization pull-in method. Here, a case where this synchronization pull-in method is used in the OFDM communication apparatus according to Embodiment 1 is explained as an example with reference to Embodiment 13 and using FIG.24.

FIG.24 is a block diagram showing a configuration of the OFDM communication apparatus according to Embodiment 14 of the present invention. In FIG.24, the

same parts as those in FIG.5 and FIG.23 are assigned the same codes as those in FIG.5 and FIG.23 and their detailed explanations are omitted.

In the present embodiment, a frame similar to the  
5 frame (FIG.22) in Embodiment 13 is used. Here, since a signal pattern with signals only placed on every (integer multiple of n)th subcarrier is used, synchronization symbol 1801 in the frame shown in FIG.22 consists of a same waveform repeated at every 1/n cycle. The following  
10 is an example where n = 4 is assumed, however, it goes without saying that the present invention is also applicable to cases where n is changed as appropriate.

In the reception section, the signal output from A/D converter 107 (reception signal) is sent to FFT  
15 section 113, multiplier 2002 and delay section 2001. Delay section 2001 outputs the reception signal delayed by 1/n symbol to multiplier 2002. Since n = 4 is assumed here, delay section 2001 delays the reception signal by 1/4 symbol. Multiplier 2002 finds a correlation between  
20 the signal output from A/D converter 107 and the signal output from delay section 2001. That is, multiplier 2002 finds a correlation between the reception signal and this reception signal delayed by 1/4 symbol. The correlation result from multiplier 2002 is sent to accumulation  
25 section 110 where the same processing as that in Embodiment 1 above is carried out.

In the present embodiment, as shown in FIG.22, 0 symbol 1802 is inserted after synchronization symbol

1801 in a signal frame. Therefore, under circumstances  
under which tens of delay signals are received, if  
signals with high power are included, correlation  
processing is carried out between the 0 symbol of the  
5 reception signal and the synchronization symbol when a  
correlation is found between the reception signal and  
this reception signal delayed by 1/4 symbol. In this  
case, since correlation processing is performed with the  
0 symbol, the correlation result becomes very small no  
10 matter how high the signal power may be. For this reason,  
a peak exceeding a threshold is identified near the FFT  
processing start timing, thus making it possible to  
accurately detect the FFT processing start timing.

As shown above, since the OFDM communication  
15 apparatus of the present embodiment has the 0 symbol  
inserted immediately after the synchronization symbol  
used for synchronization pull-in processing, making it  
possible to reduce correlation output near the  
synchronization timing position. Therefore, the  
20 present embodiment can suppress a correlation value  
exceeding a threshold even if signals with high power  
are included. As a result, the present embodiment can  
accurately detect FFT processing start timing and  
prevent desynchronization.

25 The present embodiment explains the case where the  
synchronization pull-in method above is used for the OFDM  
communication apparatus according to Embodiment 1, but  
the present invention is also applicable to cases where

the synchronization pull-in method above is used for Embodiments 2 to 12.

The OFDM communication apparatus of the present invention is applicable to a communication terminal 5 apparatus such as a mobile station apparatus and a base station apparatus in a radio communication system.

Embodiments 1 to 14 explain cases where a 0 symbol (signal) or inverted symbol (signal) is inserted immediately after a phase reference symbol used for delay 10 detection, but the present invention is also applicable to a case where a 0 symbol (signal) or inverted symbol (signal) is inserted immediately after a pilot symbol, which is a phase reference symbol used for synchronization detection. In this case, demodulation 15 section 114 carries out coherent detection instead of delay detection.

The present invention is not limited to Embodiments 1 to 14 above, but can be implemented with various modifications. Moreover, Embodiments 1 to 14 above can 20 be implemented in various combinations thereof as appropriate.

Furthermore, the present invention is explained when applied to cases where the above methods are used as the synchronization pull-in method. However, the 25 present invention is not limited to this, but is applicable to cases where any synchronization pull-in method is used which adopts steps of calculating a correlation value using the reception signal and

detecting a maximum value of the calculation result. At this time, it goes without saying that a correlation value suppression signal is inserted immediately after a symbol used for the synchronization pull-in processing,  
5 that is, a symbol used for correlation value calculation processing.

As explained above, the OFDM communication apparatus of the present invention inserts a 0 symbol (0 signal), which is a correlation value suppression  
10 signal, or inverted symbol (inverted signal) after a phase reference symbol used for delay detection or a pilot symbol used for synchronization detection, making it possible to accurately detect FFT processing start timing and prevent desynchronization even under  
15 circumstances under which tens of delay signals are received.

The present invention is not limited to the above described embodiments, and various variations and modifications may be possible without departing from the  
20 scope of the present invention.

This application is based on the Japanese Patent Application No. HEI 11-215459 filed on July 29, 1999, and the Japanese Patent Application No. HEI 10-308913 filed on October 29, 1998, entire content of which is expressly  
25 incorporated by reference herein.

What is claimed is:

1. An OFDM communication apparatus comprising:  
a transmitter having adder for adding a symbol used  
5 for synchronization pull-in to a valid symbol and  
inserter for inserting a correlation value suppression  
signal immediately after the symbol; and  
a receiver having correlation value calculator for  
calculating a correlation value using a reception signal  
10 and symbol synchronizer for establishing symbol  
synchronization by carrying out threshold judgment on  
the calculated correlation value.
2. The OFDM communication apparatus according to  
claim 1, wherein said adder uses a synchronization symbol  
15 and phase reference symbol which is identical to the  
synchronization symbol as the symbol used for  
synchronization pull-in, and the correlation value  
calculator comprises delay for delaying the reception  
signal by a unit symbol and multiplies the reception  
20 signal and the reception signal delayed by the unit  
symbol.
3. The OFDM communication apparatus according to  
claim 1, wherein said adder uses a synchronization symbol  
and phase reference symbol which is identical to the  
25 synchronization symbol as the symbol used for  
synchronization pull-in, and the correlation value  
calculator comprises IFFT-processor for IFFT-processing  
the phase reference symbol and multiplies the reception

signal and the IFFT-processed phase reference symbol.

4. The OFDM communication apparatus according to  
claim 3, wherein the correlation value calculator  
further comprises hard decider for carrying out hard  
5 decision on the IFFT-processed phase reference symbol  
and multiplies the reception signal and the phase  
reference symbol subjected to IFFT-processing and hard  
decision.

5. The OFDM communication apparatus according to  
10 claim 1, wherein the transmitter uses a synchronization  
symbol as the symbol used for synchronization pull-in  
and the correlation value calculator comprises IFFT-  
processor for IFFT-processing the synchronization  
symbol and multiples the reception signal and the  
15 IFFT-processed synchronization symbol.

6. The OFDM communication apparatus according to  
claim 1, wherein the transmitter uses a synchronization  
symbol with a same waveform repeated at every  $1/n$  cycle  
as the symbol used for synchronization pull-in, the  
20 correlation value calculator comprises delayer for  
delaying the reception signal by  $1/n$  unit symbol and  
multiplies the reception signal and the reception signal  
delayed by  $1/n$  unit symbol.

7. The OFDM communication apparatus according to  
25 claim 2 or claim 3, wherein the interval of the  
correlation value suppression signal is shorter than the  
cycle of the phase reference symbol.

8. The OFDM communication apparatus according to

claim 5 or claim 6, wherein the interval of the correlation value suppression signal is shorter than the cycle of the synchronization symbol.

9. The OFDM communication apparatus according to  
5 claim 1, wherein the receiver comprises detector for  
detecting the level of the reception signal and the  
symbol synchronizer establishes symbol synchronization  
based on the information of the level and the result of  
threshold judgment.

10 10. The OFDM communication apparatus according to  
claim 1, wherein the transmitter further comprises  
interval changer for adaptively changing the interval  
of the correlation value suppression signal according  
to a communication environment.

15 11. The OFDM communication apparatus according to  
claim 1, wherein the transmitter further comprises level  
changer for changing the level of the correlation value  
suppression signal according to a communication  
environment.

20 12. The OFDM communication apparatus according to  
claim 11, wherein the transmitter increases the level  
of the correlation value suppression signal based on an  
average value of quality information of the reception  
signal.

25 13. The OFDM communication apparatus according to  
claim 1, wherein the correlation value suppression  
signal is selected from among groups of null symbols,  
null signals, inverted symbols with the polarity of the

symbol used for the synchronization pull-in inverted and inverted signals with the polarity of the symbol used for the synchronization pull-in inverted.

14. A base station apparatus comprising an OFDM communication apparatus, said OFDM communication apparatus comprising:

a transmitter having adder for adding a symbol used for synchronization pull-in to a valid symbol and inserter for inserting a correlation value suppression signal immediately after the symbol; and

a receiver having correlation value calculator for calculating a correlation value using a reception signal and symbol synchronizer for establishing symbol synchronization by carrying out threshold judgment on the calculated correlation value.

15. A communication terminal apparatus comprising an OFDM communication apparatus, said OFDM communication apparatus comprising:

a transmitter having adder for adding a symbol used for synchronization pull-in to a valid symbol and inserter for inserting a correlation value suppression signal immediately after the symbol; and

a receiver having correlation value calculator for calculating a correlation value using a reception signal and symbol synchronizer for establishing symbol synchronization by carrying out threshold judgment on the calculated correlation value.

16. An OFDM communication method comprising:

the transmitting step having the steps of adding a symbol used for synchronization pull-in to a valid symbol and inserting a correlation value suppression signal immediately after the symbol; and

- 5        the receiving step having the steps of calculating a correlation value using a reception signal and establishing symbol synchronization by carrying out threshold judgment on the calculated correlation value.

## ABSTRACT OF THE DISCLOSURE

Synchronization symbol insertion section 102 inserts a synchronization symbol into a signal 5 digital-modulated by modulation section 101. 0 symbol insertion section 103 inserts a 0 symbol into the signal with the synchronization symbol inserted. The signal with the synchronization symbol and 0 symbol inserted in this way is sent to IFFT section 104 to be subjected 10 to an IFFT calculation. Then, guard interval insertion section 105 inserts a guard interval into the IFFT-transformed signal waveform. Then, the signal with the guard interval inserted in this way is D/A-converted by D/A converter 106. The D/A-converted signal is 15 subjected to normal radio transmission processing and then transmitted.

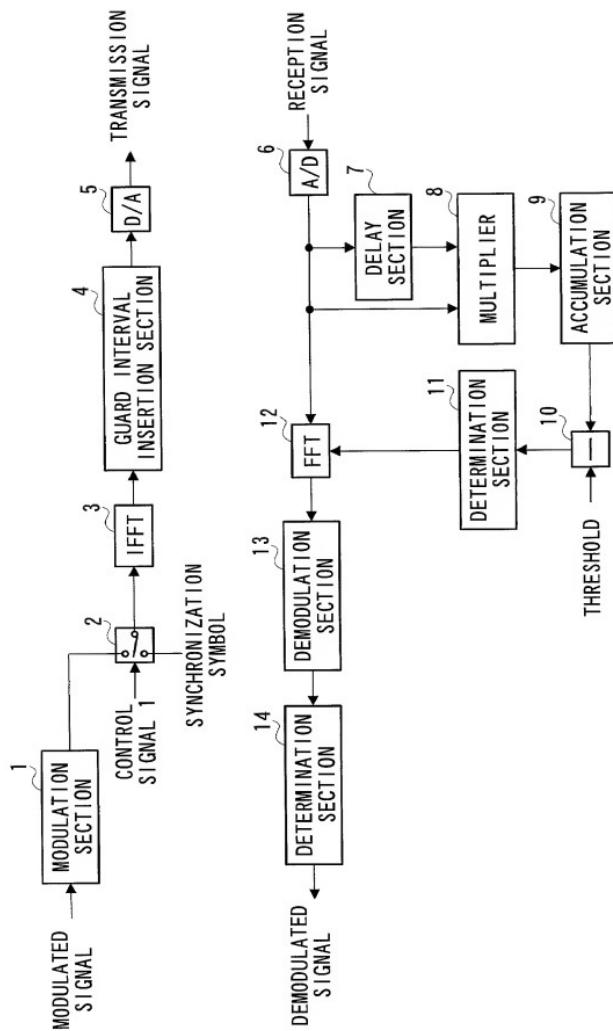


FIG. 1

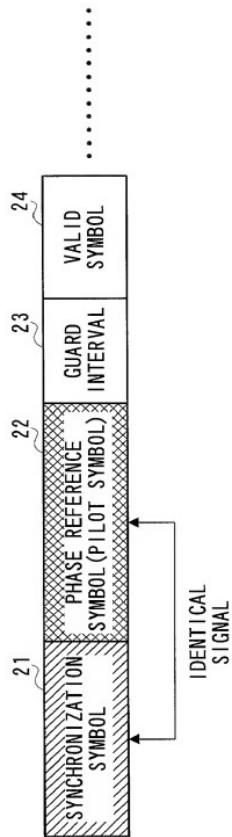


FIG. 2

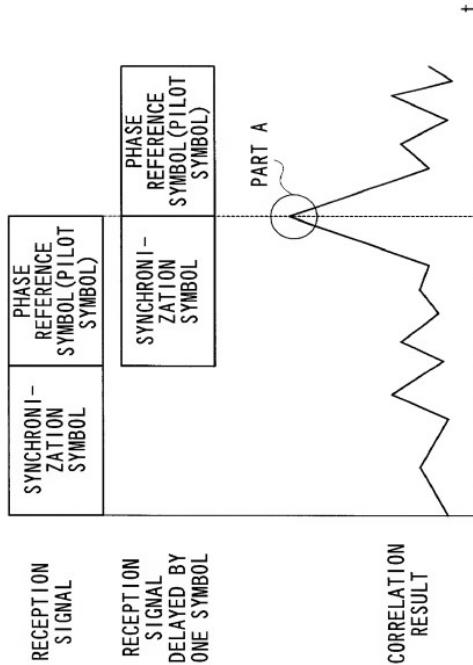


FIG. 3



FIG. 4

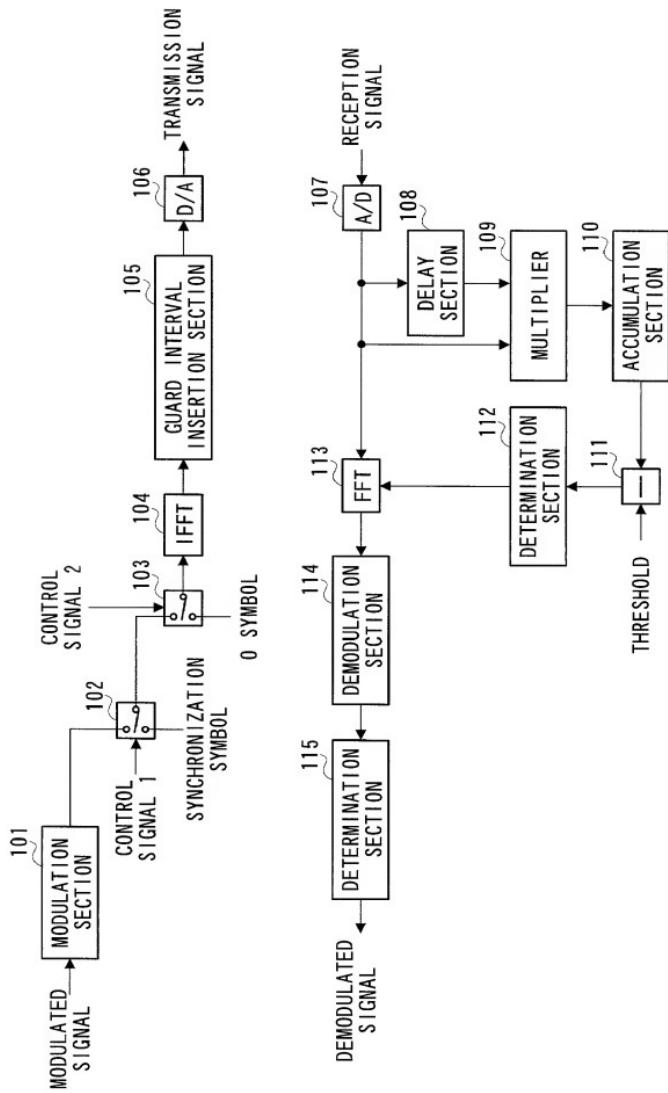


FIG. 5

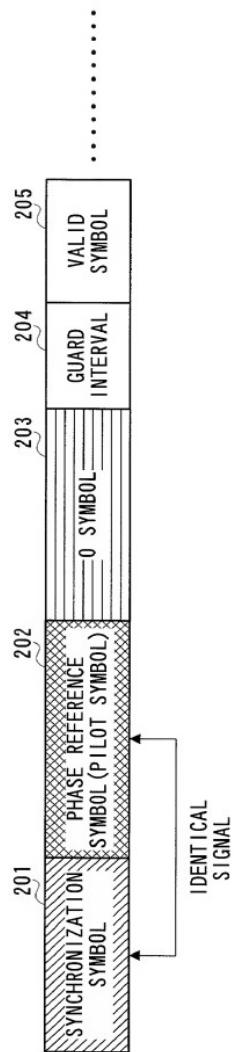


FIG. 6

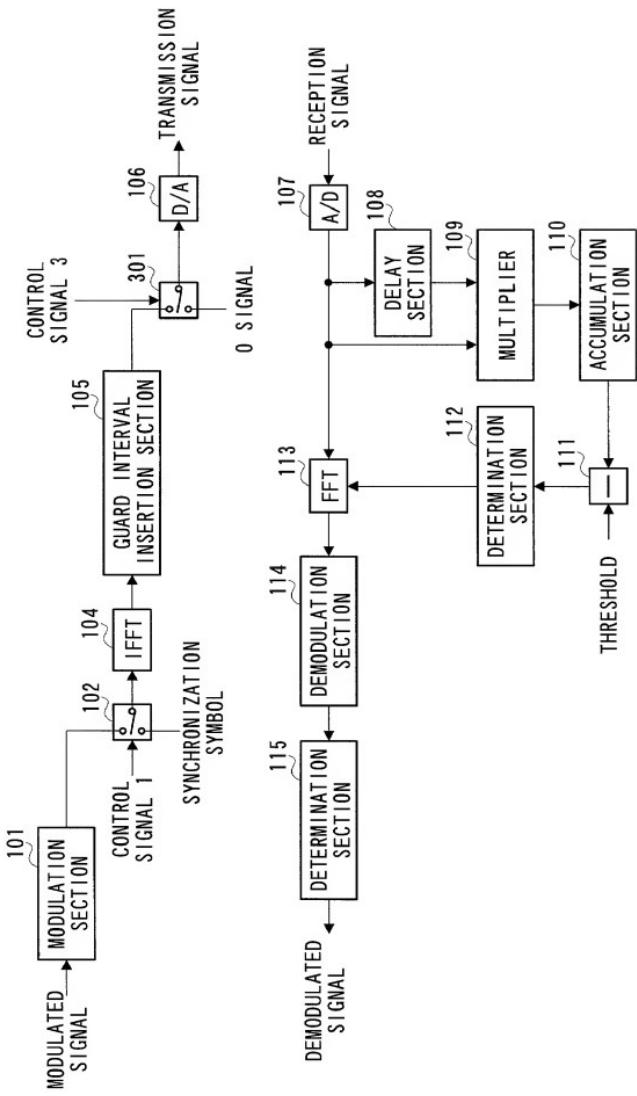


FIG. 7

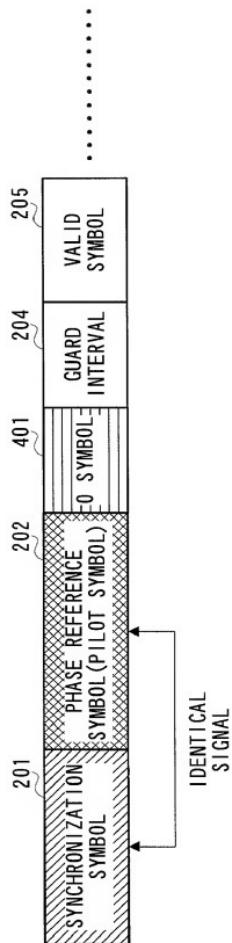
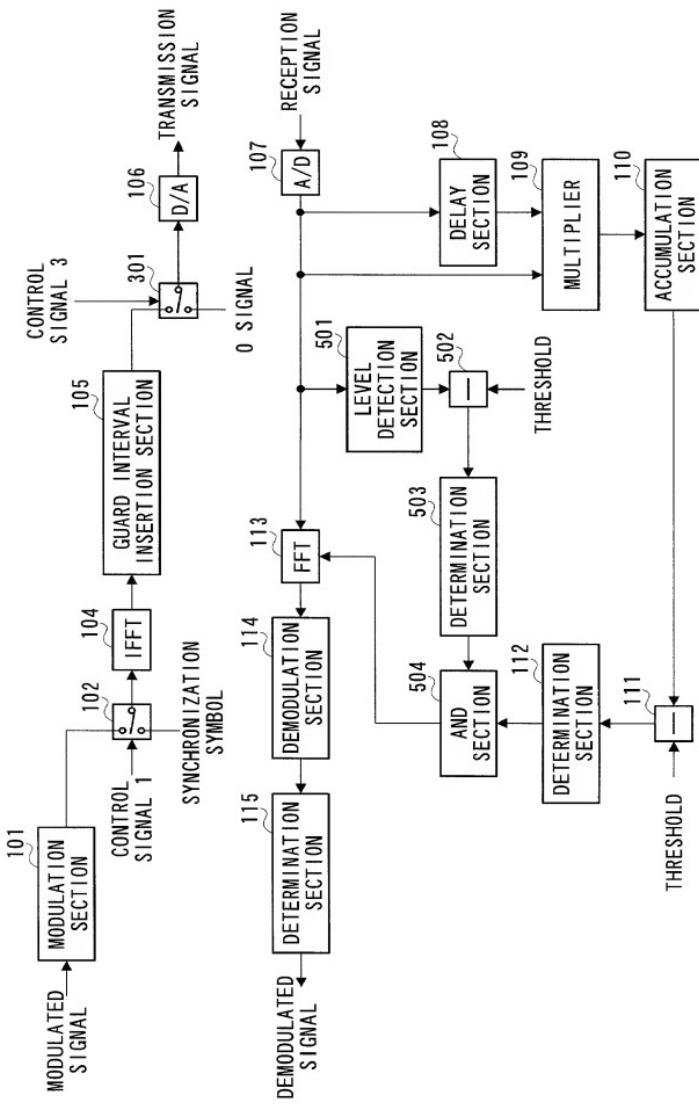


FIG. 8



E | G 9

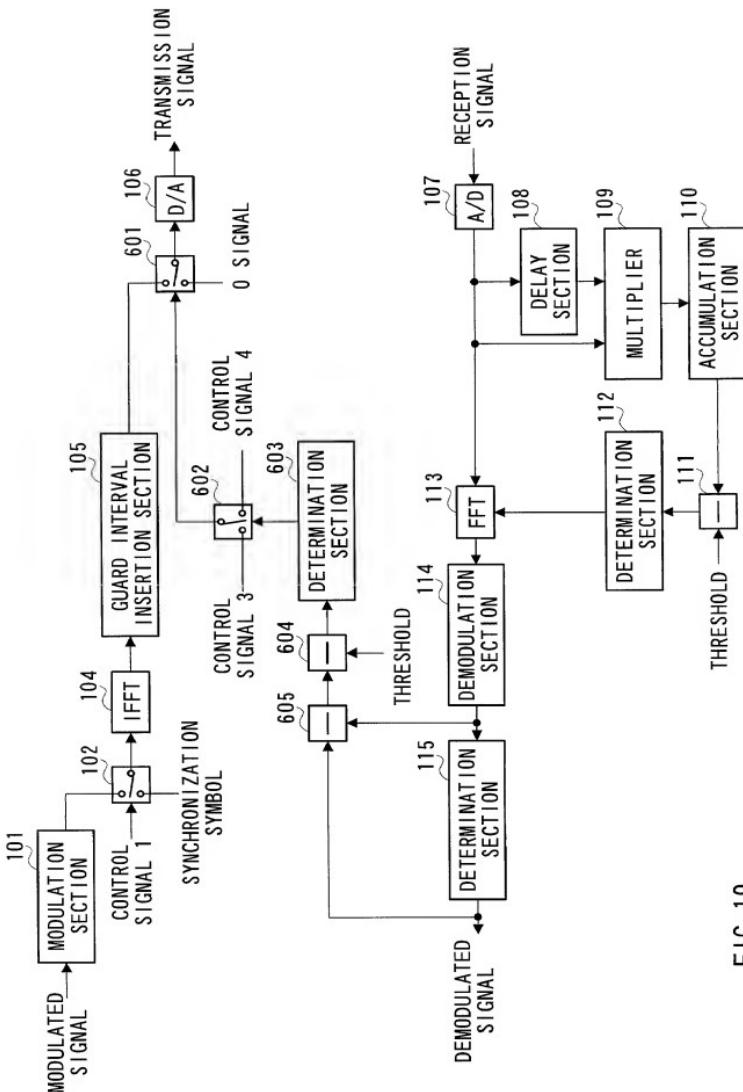


FIG. 10

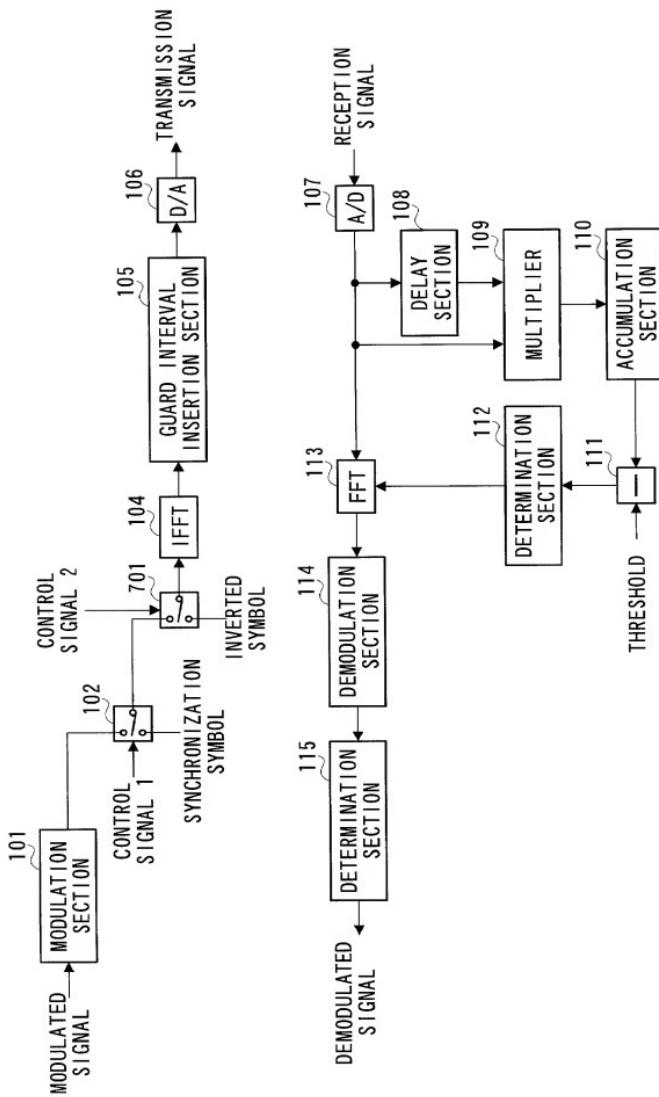


FIG. 11

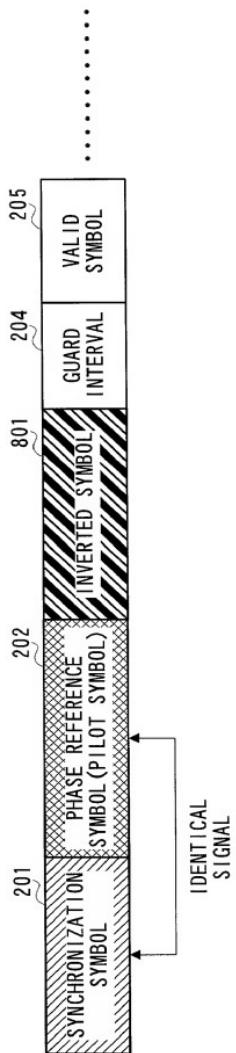


FIG. 12

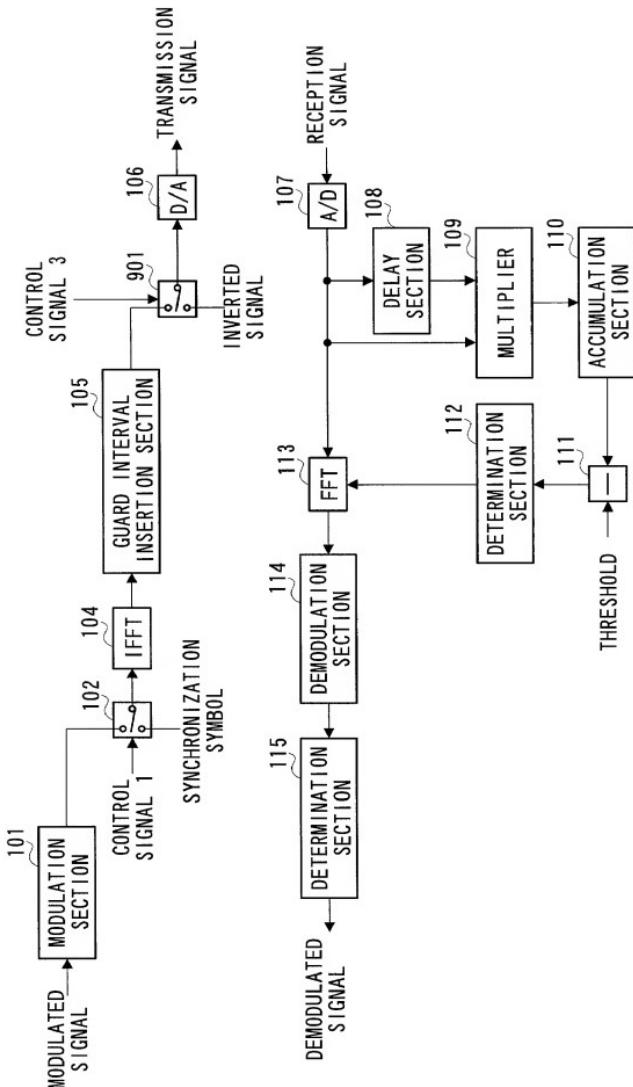


FIG. 13

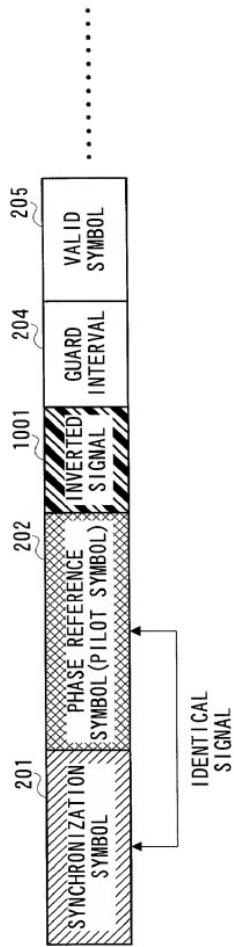


FIG. 14

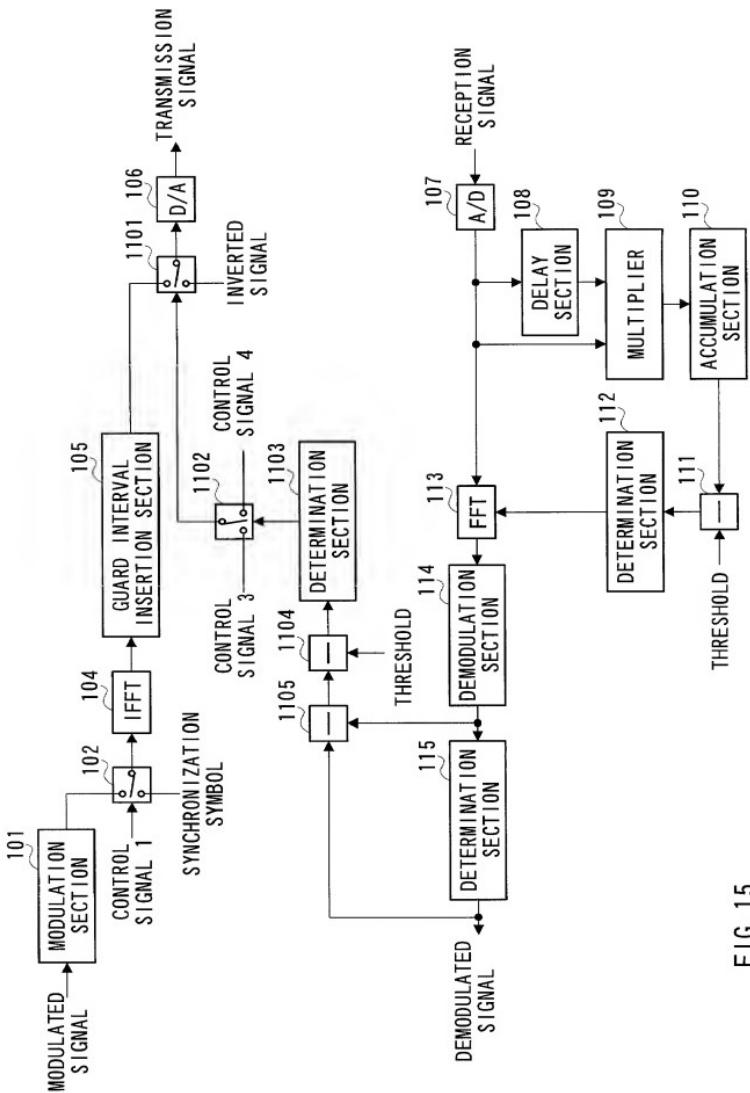


FIG. 15

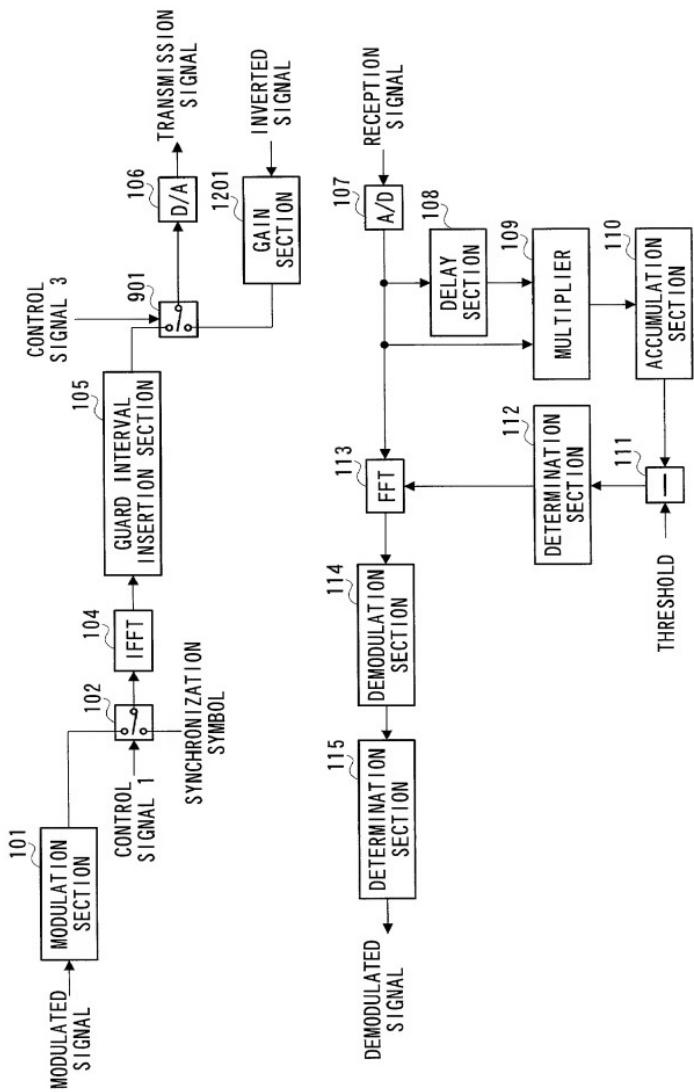


FIG. 16

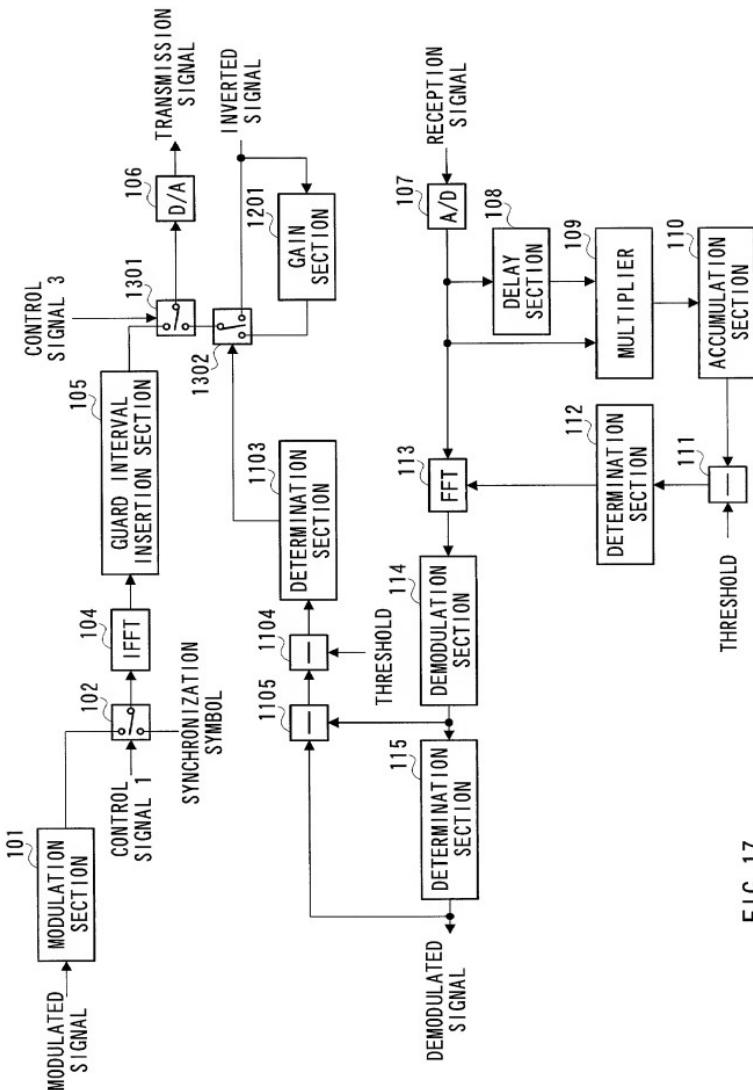


FIG. 17

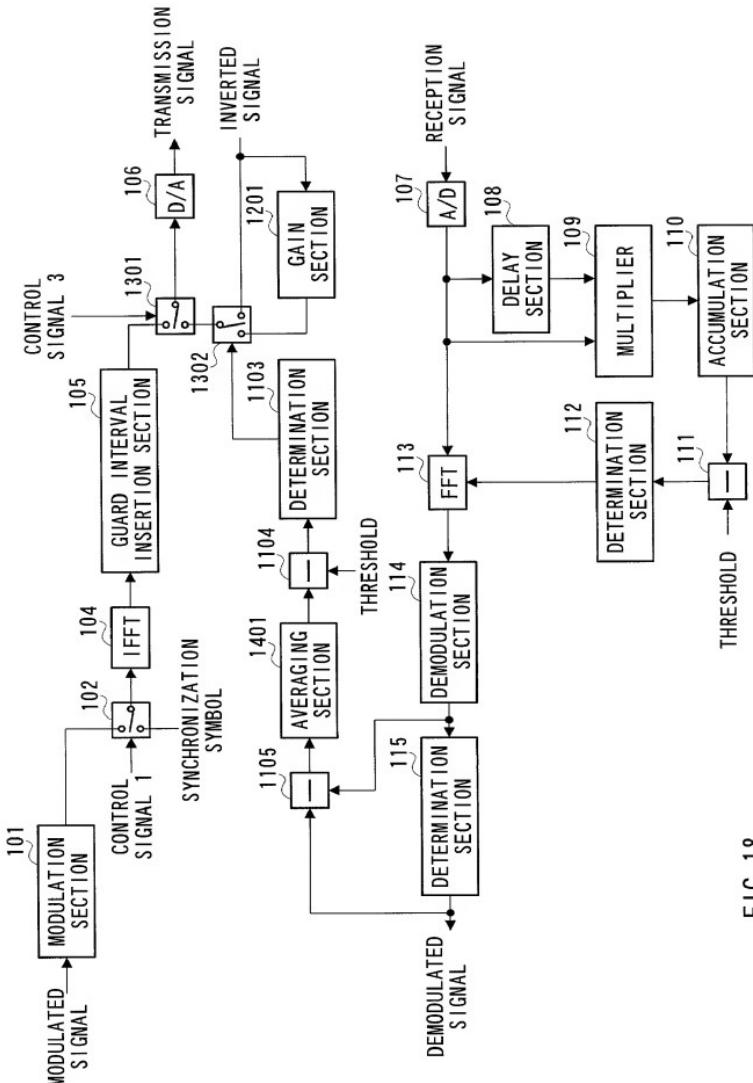


FIG. 18

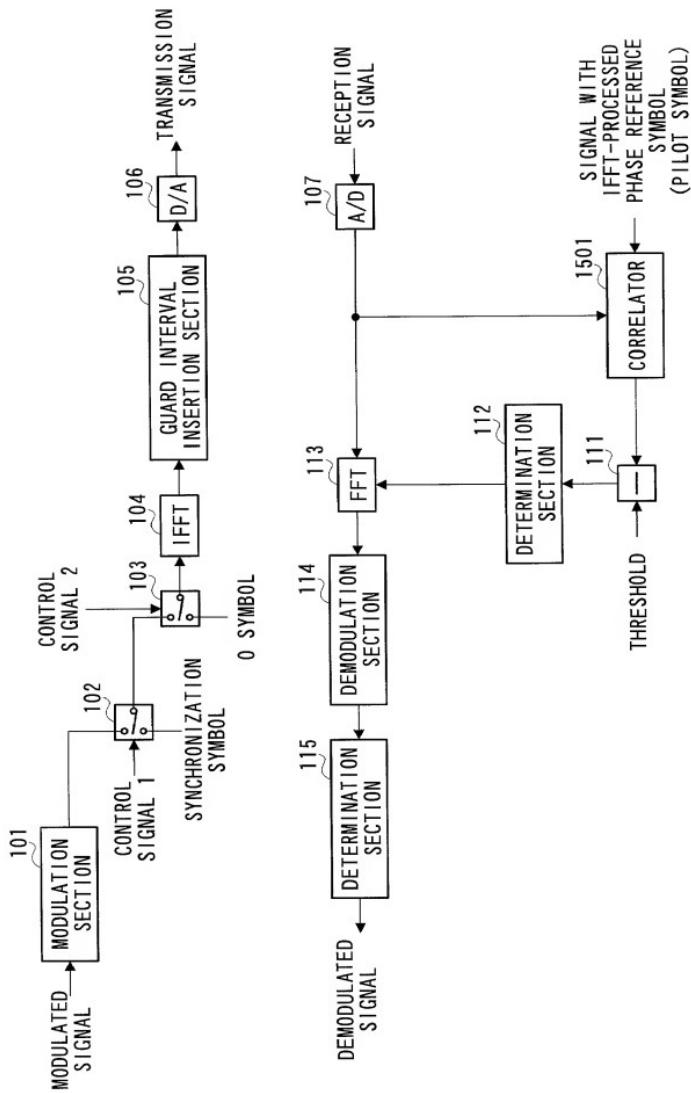


FIG. 19

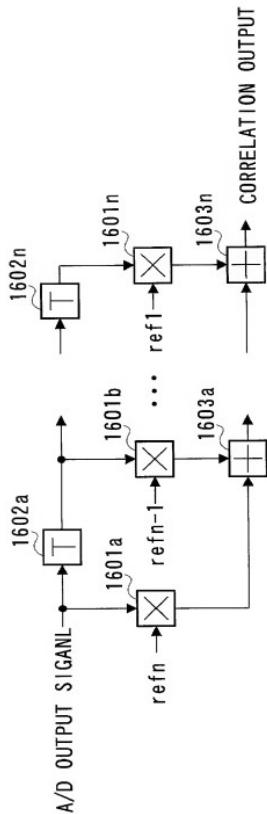


FIG. 20

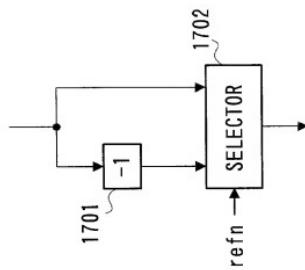


FIG. 21

GOVERNMENT OF CANADA

SYNCHRONIZATION SYMBOL	1801	1802	1803	1804	1805	1806	.....
			PHASE REFERENCE SYMBOL (PILOT SYMBOL)	PHASE REFERENCE SYMBOL (PILOT SYMBOL)	GUARD INTERVAL	VALID SYMBOL	

FIG. 22

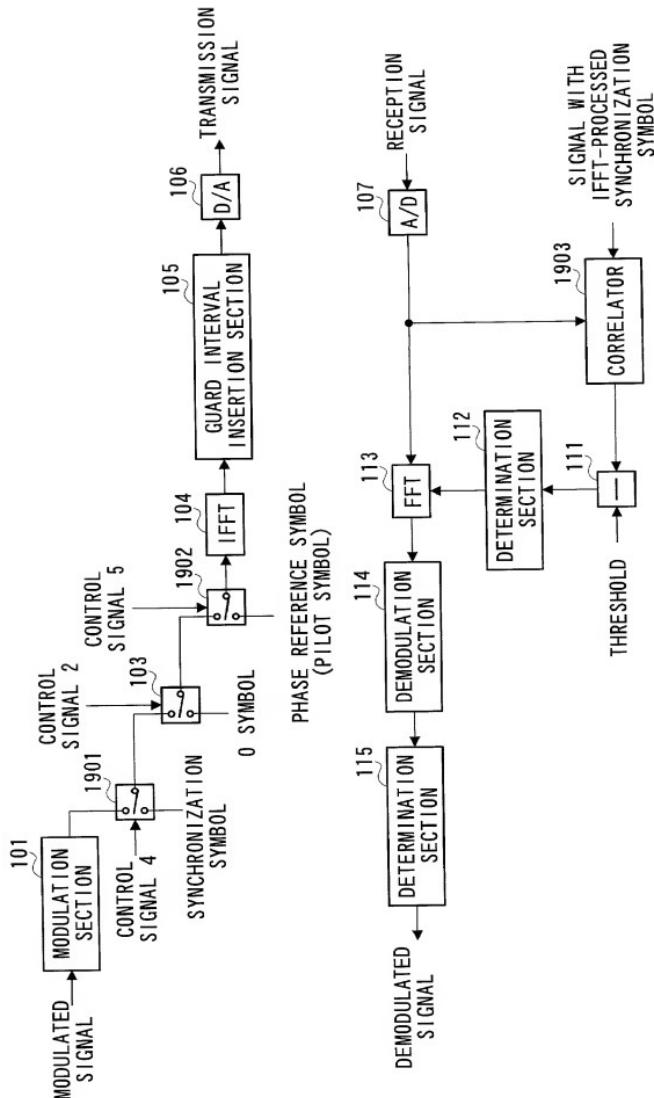


FIG. 23

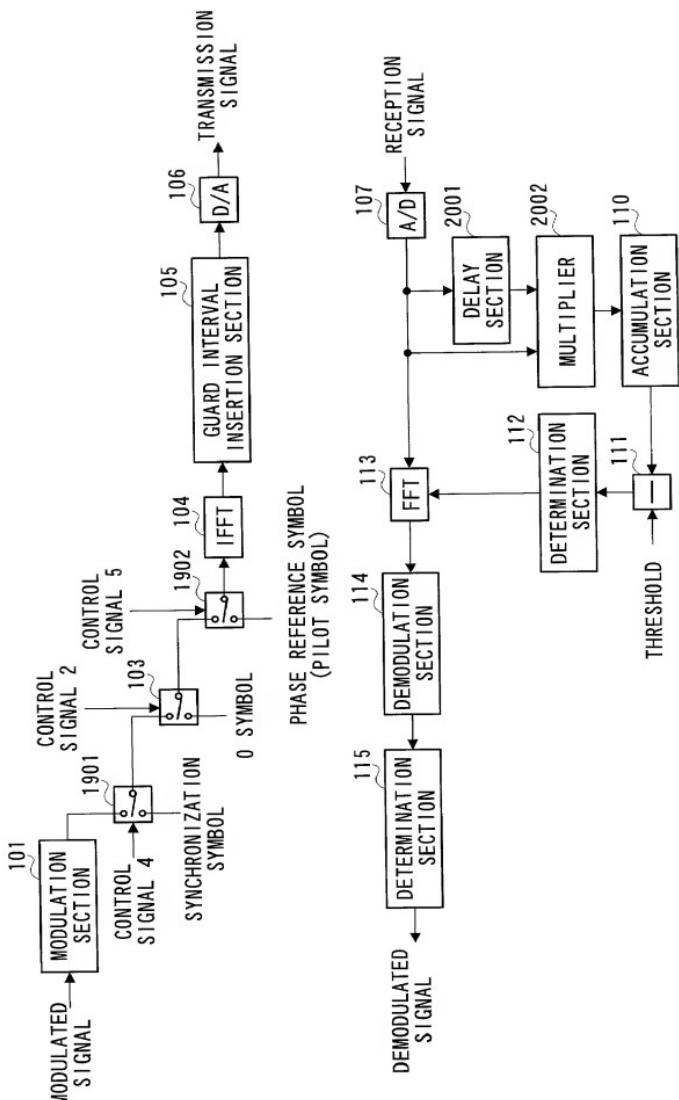


FIG. 24

**APPLICATION FOR UNITED STATES PATENT**  
**Declaration for Patent Application**

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on

the invention entitled: OFDM COMMUNICATION APPARATUS

the specification of which

2 (file no. \_\_\_\_\_)

(check at least one)

3 [x] is attached hereto

4 [ ] was filed on \_\_\_\_\_ as (5) U.S. Application Serial No. \_\_\_\_\_

6 [ ] and was amended \_\_\_\_\_

(if applicable)

Use this portion only if you are entering the U.S. National phase based on a PCT International Application designating the U.S.

7 [x] was filed as PCT international application

8

Number \_\_\_\_\_

9

on \_\_\_\_\_

and was amended under PCT Article(s) 19 and/or 34

10

on \_\_\_\_\_ (if applicable).

I hereby declare that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended, by any amendment referred to above.

I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me which is material to patentability in accordance with Title 37, Code of Federal Regulations, §1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date earlier than that of the application(s) on which priority is claimed.

Prior (Foreign) Application(s) and Priority Claims Under 35 U.S.C. 119

Priority Claimed

11a	<u>Japan</u> (Country)	<u>H10-308913</u> (Number)	<u>29/10/1998</u> (Day/Month/Year Filed)	<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No
-----	---------------------------	-------------------------------	---	------------------------------	--

[ ] Additional foreign application numbers are listed on a supplemental priority data sheet attached hereto.

Priority Claim(s) from U.S. Provisional Application(s) – I hereby claim the benefit under Title 35, United States Code, §119(e) of any United States provisional application(s) listed below:

11b	Application No.	Day/Month/Year Filed	Application No.	Day/Month/Year Filed
-----	-----------------	----------------------	-----------------	----------------------

<p>Do not use this portion to identify a PCT application if the parent application is the U.S. National phase of the PCT application</p>	I hereby claim the benefit under Title 35, United States Code, 120 of any United States application(s) or PCT international application(s) designating the United States of America that is/are listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in that/those prior application(s) in the manner provided by the first paragraph of Title 35, United States Code §112, I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, §1.56 which became available between filing date of the prior application and the national or PCT international filing date of this application.			
--	---	--	--	--

13	<u>(U.S. Application Number)</u>	<u>(U.S. Filing Date)</u>	Status (patented, pending, abandoned)
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I hereby appoint the following attorneys of the firm of Stevens, Davis, Miller & Mosher, L.L.P. as my attorneys of record with full power of substitution and revocation to prosecute this application and to transact all business in the Patent and Trademark Office:

James E. Ledbetter, Reg. No. 28732; Thomas P. Pavelko, Reg. No. 31689; and Anthony P. Venturino, Reg. No. 31674.

**ALL CORRESPONDENCE IN CONNECTION WITH THIS APPLICATION SHOULD BE SENT TO  
STEVENS, DAVIS, MILLER & MOSHER, L.L.P., 1615 L Street, N.W., Suite 850, Washington, D.C. 20036,  
TELEPHONE (202) 408-5100, FACSIMILE (202) 408-5200.**

See page 2 for signature lines

**STEVENS, DAVIS, MILLER & MOSHER, L.L.P.**

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful statements may jeopardize the validity of the application or any patent issuing thereon.

**PAGE 2 OF U.S.A. DECLARATION FORM**13a Typewritten Full Name  
of Sole or First Inventor

Hiroaki	SUDO
Given Name	Middle Name

14a Inventor's Signature

Hiroaki	Sudo
---------	------

15a Date of Signature

March	21	2000
Month	Day	Year

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City	State or Province	Country

17a Citizenship

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address, including country)

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<b>Yokohama-shi, Kanagawa 224-0054 JAPAN</b>

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<b>Kimihiko</b>	<b>ISHIKAWA</b>
Given Name	Middle Name

14b Inventor's Signature

Kimihiko	Ishikawa
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15b Date of Signature

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Month	Day	Year

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17b Citizenship

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(Insert complete mailing  
address, including country)

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<b>Yokohama-shi, Kanagawa 233-0001 JAPAN</b>

13c Typewritten Full Name  
of Sole or First Inventor

Given Name	Middle Name	Family Name
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14c Inventor's Signature

--

15c Date of Signature

Month	Day	Year
-------	-----	------

16c Residence

City	State or Province	Country
------	-------------------	---------

17c Citizenship

--

18c Post Office Address  
(Insert complete mailing  
address, including country)

--

13d Typewritten Full Name  
of Sole or First Inventor

Given Name	Middle Name	Family Name
------------	-------------	-------------

14d Inventor's Signature

--

15d Date of Signature

Month	Day	Year
-------	-----	------

16d Residence

City	State or Province	Country
------	-------------------	---------

17d Citizenship

--

18d Post Office Address  
(Insert complete mailing  
address, including country)

--

\*Note to Inventor: Please sign name on line 15 exactly as it appears on line 14 and insert the actual date of signing on line 16. If there are more than four inventors, please add a copy of this page for identification and signatures for the additional inventors.